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Pesticides in Natural Systems: 'How Can Their Effects Be Monitored'. Proceedings of the Conference. Held in Corvallis, Oregon on December 11-12, 1990

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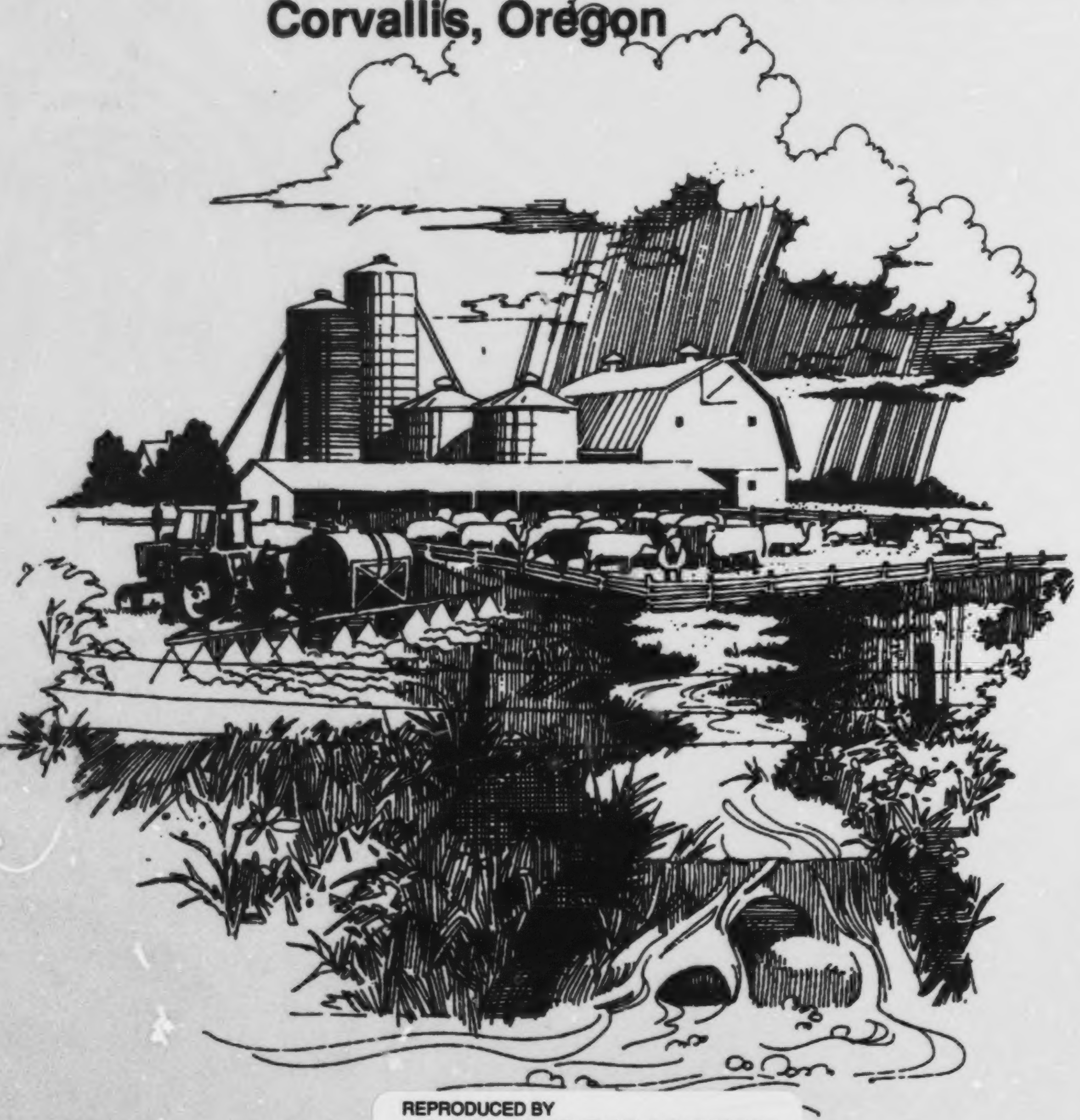
EPA

Pesticides in Natural Systems:
How Can Their Effects Be Monitored?

Proceedings of the Conference
December 11th and 12th, 1990
Corvallis, Oregon



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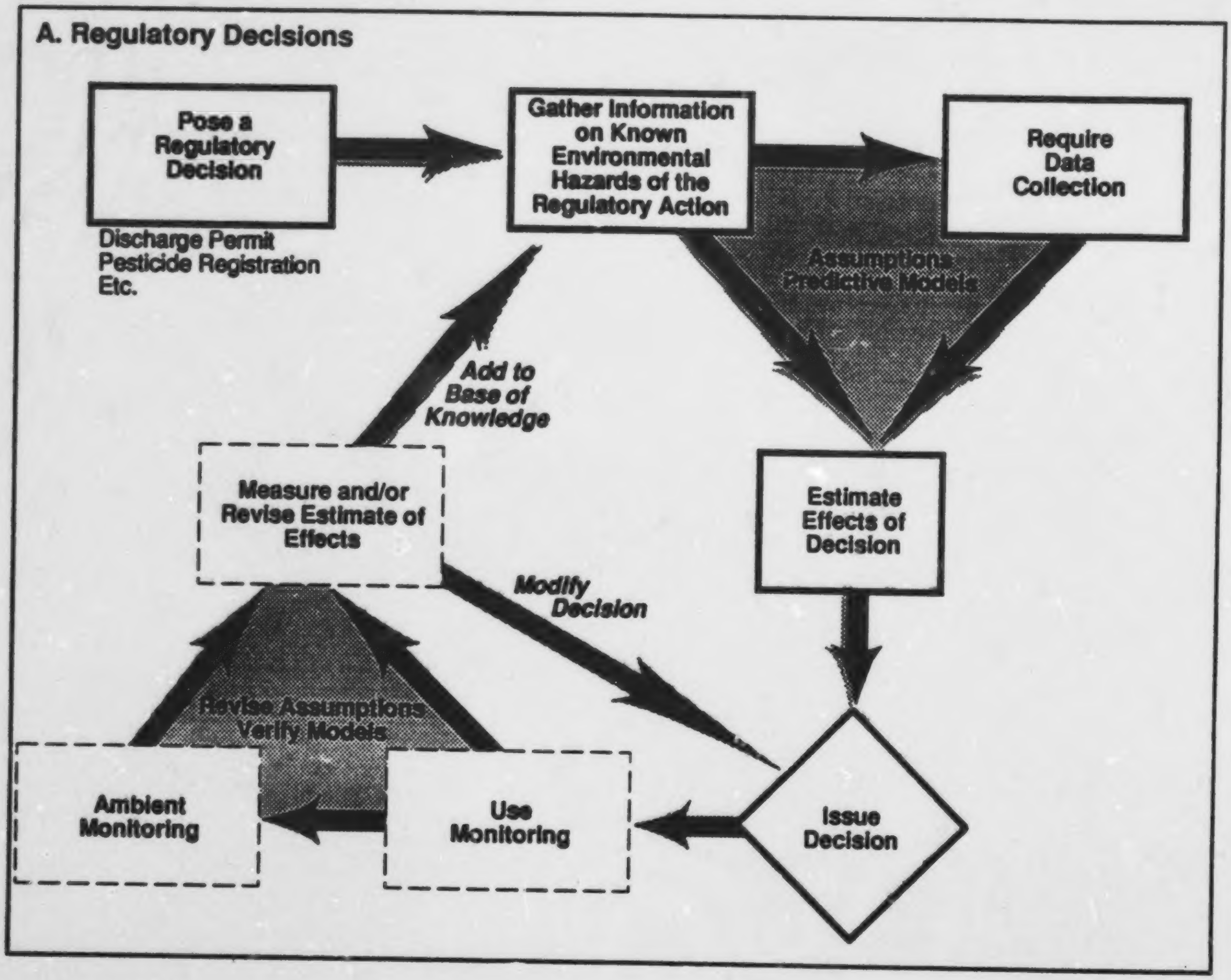
Typical Environmental Regulatory Decision Loops


A. Regulatory Decisions

Pose a Regulatory Decision
Discharge Permit
Pesticide Registration
Etc.
Gather Information on Known Environmental Hazards of the Regulatory Action
Require Data Collection
Assumptions
Predictive Models
Estimate Effects of Decision
Issue Decision
Use Monitoring
Ambient Monitoring
Revise Assumptions
Verify Models
Measure and/or Revise Estimate of Effects
Modify Decision
Add to Base of Knowledge

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A collection of papers representing some of the reports given at a Conference on the same subject held December 11 and 12 at Corvallis Oregon. The 10 papers are grouped under the headings, Aquatic Systems, Terrestrial Systems, Theoretic Studies, and Frameworks for Longterm Monitoring. The first three sessions include papers dealing with Puget Sound, upland game birds, "reference" watercourses, lichens as biomonitors, effects of a fungicide on soil communities, and mathematical methods of ordering data into meaningful groups. The last session contained a paper on EPA's Ecological Monitoring and Assessment Program, EMAP, and the US Geological Survey's River Basin Surveys (The Yakima River represents a pilot for these studies. Two of the papers served as focus papers on the subjects of Biomonitoring and Risk Assessment, respectively. Each of these two papers is followed by a transcript of the discussion which took place in a workshop on the same theme. The volume includes abstracts of papers not reproduced there in full. The conference, and this volume, are an initial step in the Region's Pesticide Monitoring Strategy, which will provide a better understanding of the unintended effects of pesticide use on natural ecosystems.

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PROCEEDINGS OF THE CONFERENCE:

PESTICIDES IN NATURAL SYSTEMS: HOW CAN THEIR EFFECTS BE MONITORED?

Organized by the Pesticides Section, Region 10

United States Environmental Protection Agency

Hosted by the Environmental Research Laboratory
Office of Research and Development

at

Corvallis, Oregon

December 11 and 12, 1990

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INTRODUCTION:

Region 10's Ecological Monitoring Strategy for Pesticides

Many EPA programs utilize some type of ambient monitoring as an integral part of their environmental management efforts. The reasons are intuitively obvious. The monitoring provides verification of project specific decisions, and it provides long term trend information that is valuable for reordering priorities and fine tuning programs. Thus, NPDES permits and dredge and fill permits often include ambient monitoring requirements which are intended to test assumptions and verify models that were the basis for the permit's issuance. The permit requirements can then be adjusted, if appropriate, based on the monitoring results. Ambient monitoring also has been valuable in identifying trends that require program adjustments. Trends that were detected and are being monitored in this way include acid rain and concurrent lake deterioration, ozone depletion and global warming, lake eutrophication, dioxin contamination of surface water and more. Figure 1 (inside front cover) depicts the typical environmental decision process. It is a closed loop process. The ambient monitoring closes the decision loop by evaluating the initial decision, which then can be revised if appropriate or, at the other extreme, used as a model for similar future situations.

In the Pesticides Program the process tends to stop at the dashed lines. It is not a closed loop. Little effort is made to evaluate the program decisions. Region 10 believes that it is important to apply the concept of ambient monitoring to the pesticide program in the Pacific Northwest and close the loop in Figure 1. That is the purpose of the Ecological Pesticides Monitoring Strategy.

There are currently about 50,000 registered pesticide products available in the United States. In 1987, 1.8 billion pounds of active ingredients of conventional pesticides were used in the United States. That number increases to 2.7 billion pounds if wood preservatives, disinfectants, and sulfur are included in the accounting. By definition, pesticides are toxic and present a risk to nontarget organisms and natural systems, but they are also an integral part of society, and great benefits are derived from their use. Registration of a pesticide for use in this country depends on a finding by EPA that its benefits outweigh the risks it poses to the environment. To verify this risk/benefit relationship, FIFRA requires the submittal of considerable data before a pesticide can be registered. This data requirement includes substantial information pertaining to the ecological risks. Many aspects of the ecological risk posed by a pesticide are understood when the pesticide is registered. Indeed, pesticides are not registered if the apparent risks they pose to the environment exceed the benefits of their use. But, if the benefits of the pesticide are significant, the risks tolerated can be significant.

It should be kept in mind that the submitted data are from controlled studies and may not actually reflect how pesticides are used in the real world. Furthermore, the agency test requirements for ecological effects reflect a limited number of species under a limited number of conditions. So even though considerable ecological data are analyzed before registering a pesticide, the decision is associated with a great deal of uncertainty. This uncertainty in conjunction with the huge quantities of toxic pesticides used makes it essential that the loop in Figure 1 be closed. That is, collect the information necessary to determine the consequences of those risk benefit decisions, to determine if the risk/benefit analyses are accurate, and to ensure the ecological hazards are understood.

We know enough about ecology, the science, to know that we don't fully understand the many ways that pesticides could affect natural systems. Basically we know that everything effects everything else. This uncertainty regarding the ecological affects of pesticide use is perhaps, the major reason that pesticides consistently rank in the highest risk category in comparative risk evaluations.

The EPA has, during the past 5 years, conducted a number of comparative risk evaluations. At EPA Headquarters, a task force compared the relative risks posed by environmental problems faced by the agency. In their 1987 report, "Unfinished Business", pesticides were ranked with the highest risks to natural environments.

In 1987, Region 10 conducted its own comparative risk evaluation, focussing on problems peculiar to the region. Again, pesticides were ranked in the highest risk category both for human health and for natural environments.

INTRODUCTION

In 1989 EPA's Administrator, William Reilly, asked EPA's Science Advisory Board to review the "Unfinished Business" report. The Board's Relative Risk Reduction Strategies Committee made ten recommendations. The first three of these follow:

1. EPA should target its environmental protection efforts on the basis of opportunities for the greatest risk reduction.

2. EPA should attach as much importance to reducing ecological risk as it does to reducing human health risk.

3. EPA should improve the data and analytical methodologies that support the assessment, comparison, and reduction of different environmental risks.

The SAB Committee recognized habitat alteration, loss of biological diversity, and change in community structure among the highest ecological risks. Pesticide contamination of natural systems can accentuate all of these risks.

Pesticides routinely rank high in these evaluations because the use pesticidal use really poses the ecological risk suggested by these analyses. An advisory group has been formed including persons currently involved in monitoring activities or who are in laboratories of pesticides is so great and our knowledge of their affects is so small. Region 10's Ecological Pesticides Strategy will address that concern. It will start the process to collect information to determine if capable of carrying out biological or chemical monitoring. This group will be asked to develop a model of a monitoring system which can detect ecological effects of pesticides.

The strategy addresses the three recommendations of the SAB committee given above. It seeks to improve data collection and analytical methodologies, it emphasizes ecological risk, and it seeks to acquire data to allow identification of the best risk reduction opportunities.

The question is asked, "What will this information be used for?" It won't be adequate for enforcement cases. It may reveal reductions in natural populations of some species. But, in most cases, the registration process predicts those kinds of impacts. So, what do these costly monitoring programs add?

They can monitor the health of the natural environment as it is affected by pesticide use. They can verify that the predicted impacts are the only impacts. They can address the questions of cumulative impacts and synergistic effects. This information could then be used to cancel the use of pesticides as appropriate; support the use of pesticides as appropriate; prioritize research into alternatives to chemical pesticides; identify needed changes to agency policies, procedures, and regulations; and influence the development of new legislation.

To summarize, the problem this strategy is intended to address is the lack of long term environmental trend monitoring which can measure the effects of the continual intensive use of pesticides.

The pesticide monitoring conference in Corvallis was the most significant step so far in implementation of the Ecological Monitoring Strategy. It brought together many of the people who have made significant contributions to ecological monitoring in the Region, and began the process of crystallizing the concerns, and the technical problems, which will drive the effort to devise a workable plan. This volume contains many of the technical reports, and also the free-form discussions which took place at the meeting.

Richard Parkin, Chief
Pesticides Section, Region 10
USEPA

ACKNOWLEDGEMENTS

The conference on monitoring for the effects of pesticides in natural systems took place because of a most unusual response by all participants - voluntary support based on a desire to share information about this relatively unexplored topic. All of the speakers gave extensively of their time to prepare their talks, with two months or less lead time. The number of people attending was remarkable, also. About 40 participants were expected, but 100 actually registered. The keynote speaker, William Cooper, took time from his busy schedule to give two lectures and then lead the workshop on risk assessment. He got up at 4 AM to catch a plane to his next engagement. Walt Thies arranged for two presentations and led a field trip. Anne Fairbrother, of the Environmental Research Laboratory at Corvallis, volunteered to host the conference, arranged for the excellent facilities at the LaSelles Conference Center of the University of Oregon and for an audio technician to tape the proceedings, without which this volume would have been impossible. Anne even saw that coffee was available! Then at the last minute she was asked to chair a session. Dan McKenzie, who took part as a speaker and as chair of the longest session, supported the conference and the Strategic Plan of which it was a part in numerous ways.

Many people who did not attend the conference contributed to its success, and to our ability to address the task of assessing the importance of pesticides and their residues in the natural environment. These include my fellow workers, who provided much informal training and guidance, and who suggested numerous resources to me. Over 200 people in universities, government agencies, environmental action organizations and private business answered telephone inquiries or met with us graciously and helpfully, making it possible to identify people actually working in the field.

A part of the strategic plan of which this conference was a part is the building of a database on monitoring activities in the Northwest. Special thanks are due to all of those who responded to the request for information for this database, which was signed by Karl Arne of this agency and by Alan Chartrand for the contractor, Dames and Moore.

This conference, and the initiative of which it is part, happened because of a real interest, on the part of individuals in EPA's Region 10 and at the Environmental Research Laboratory in Corvallis, in carrying their responsibility to protect the environment beyond a reactive position, to anticipate problems before they occur. This level of responsibility is essential to the health of our nation in the broadest sense. To the staff and managers of Region 10, and in particular to my boss Rick Parkin, Chief, Pesticides Section, who spent many hours conceiving the initiative and promoting its fruition, I add my personal thanks.

Michael Marsh
Editor

Dickeybirds and Dollars

Keynote Address by William Cooper

[Note: A transcript of Dr. Cooper's talk was not available, and the sound recording equipment was not functioning at the time he gave his presentation. The following, based on notes taken at the conference, summarizes the major points that he made. Ed.]

The Science Advisory Board was asked to review and amplify EPA's 1986 document, Unfinished Business. Three subcommittees were formed, one on Human Health, one on Ecology and Welfare, which Cooper chaired, and one to establish Strategic Options. The first two committees were asked to rank the risks that they were to consider.

The human health group considered the risks from pesticides in two categories, direct and indirect, and they decided that only those directly affected (applicators and other persons who handle pesticides regularly in their occupations) were at highest risk while effects on consumers were less serious.

Cooper's subcommittee was charged with dealing with risks not only from an ecological, but also from an economic standpoint (the "welfare" charge). In "Unfinished Business", the analysis of risks was performed from the standpoint of the various offices or regulatory subdivisions in the Enviromental Protection Agency. The SAB subcommittee decided that this approach was inconsistent in that it mixed sources (e. g., pesticides), receptors (e. g., indoor air), media (e. g., non-point source discharges), and specific regulatory obligations as environmental problems. An alternative ranking approach was adopted, using environmental stressors (physical, chemical, thermal, etc.,), and identifying the receptors that they are expected to affect, and then building a matrix of the anticipated severity of consequences on the basis of how extensive the effects would be in area and severity, and how long it is expected that the community would take to recover.

The rate at which natural processes occur affects the distribution and speed of effects, as well as recovery. Thus, air masses can move quickly and over long distances, while groundwater moves very slowly. In consequence, a welfare based analysis puts groundwater contamination in a lower risk category than air pollution.

To establish relative severity, indicators of effect are needed, and the conclusions reached depend heavily on these. Species diversity has not been found to be a very sensitive indicator. Structural and functional shifts in the ecosystem are much more important. Species loss is regarded as profoundly important, since recovery would take place on a time scale of millenia in many cases.

It is valuable to identify precursors to the social endpoint, so that corrective measures can be taken early.

The necessity to include welfare (human social and economic benefits) in the analysis complicates the ranking greatly. For example, salmon in the great lakes seem to thrive in an environment contaminated by PCB's, while their flesh is so heavily contaminated with the chemical as to be considered unfit for human consumption.

This analysis provided the basis for a ranking of severity of risk from each stressor on the basis of scale of the effect (local, regional or global). Pesticides were ranked high at the local, or ecosystem level, and of medium importance at the regional level. The three stressors ranking highest on global, regional and local scales were global climate, stratospheric ozone and habitat alteration.

Session I. Aquatic Systems: Rick Parkin, Chair

A. Fresh-water Systems

Ground and Surface Water Studies for Pesticides in Oregon

Greg Pettitt
Department of Environmental Quality
(abstract not submitted)

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Unimpacted streams as Referrents
in
Ecoregion Bioassessment

R.W. Plotnikoff
Washington Department of Ecology
(article)

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Department of Interior agricultural drain water programs

Carol Schuler
U.S. Fish & Wildlife Service
(abstract not submitted)

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Monitoring the Yakima River Basin

Stuart McKenzie
U.S. Geological Survey
(abstract)

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B. Salt-water and Estuarine Systems

A Strategy for Monitoring Contemporary Pesticides
Entering Estuarine Habitats

Michael Rylko
EPA 10th Region, Office of Coastal Waters

Unimpacted streams as Referrents
in
Ecoregion Bioassessment

R.W. Plotnikoff
WA Department of Ecology
Surface Water Investigations Section
Olympia, WA 98504

ABSTRACT

The Ecoregion Bioassessment Pilot Project was funded by the Timber/Fish/Wildlife (T/F/W) program for the purpose of defining characteristic surface water quality and benthic macroinvertebrate communities in forested areas of Washington. The ecoregion concept was used as a regional approach for locating replicate sites and as units within which to identify unique chemical, physical, and biological characteristics. Surface water quality was defined through monthly monitoring while benthic macroinvertebrate communities were characterized by quarterly monitoring. Six sites were chosen within each of three ecoregions, the Puget Lowland, Cascades, and Columbia Basin. Criteria for site selection were developed to identify the final eighteen monitoring sites from a total of fifty-one candidate sites. Assistance in candidate site identification was obtained from the T/F/W-Ambient Monitoring Program, US Geological Survey, and the US Forest Service. The final monitoring sites chosen for the project were reflective of physical characteristics typical of streams within each ecoregion.

INTRODUCTION

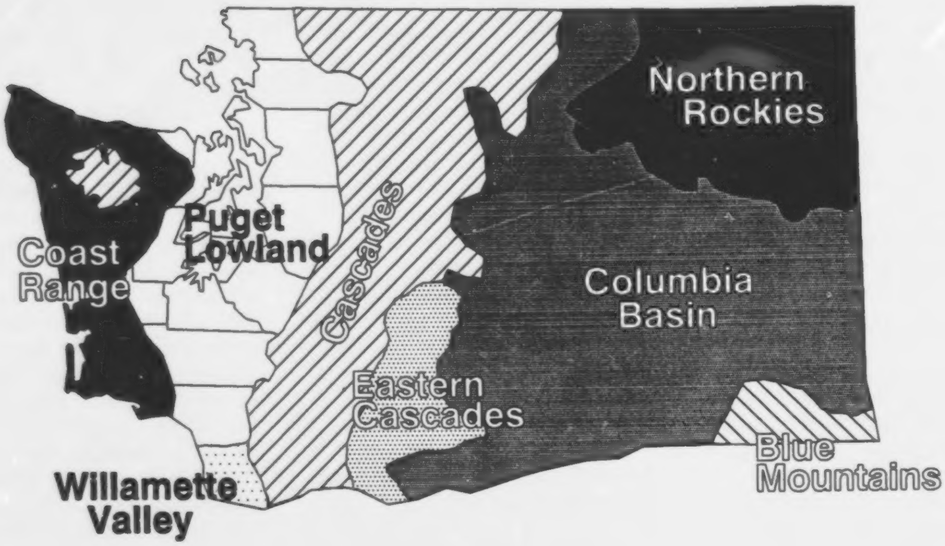
Protection of aquatic life is a common designated beneficial use of aquatic resources and is a primary reason for maintaining a high degree of water quality. Historically, chemical analyses of water column samples have been the primary means of assessing aquatic conditions, however this has not been adequate in many cases. Techniques to assess the biological community can be better measures of overall conditions. The premise behind using bioassessment as a management tool is that a more realistic overall view of aquatic conditions may be obtained through the evaluation of living organisms. Bioassessment has experienced an increasing popularity with a number of states and is endorsed by the United States Environmental Protection Agency (1989). Its present use in Washington state has been limited by a lack of regional biological information.

Bioassessment can be conducted with a variety of aquatic organisms, but the use of benthic macroinvertebrates is a more attractive approach initially. These organisms integrate water quality conditions over time and space and thus indicate the overall stream health. A combination of biological and water quality information better describes and enhances the knowledge of dynamic instream processes.

The bioassessment effort was a proposed pilot project to evaluate the efficacy of its use in Washington. This pilot project was based on the concept of ecoregion bioassessment (Whittier *et al.*, 1987) and would establish a protocol for continued use. Biological information pertaining to unimpacted aquatic systems is collected to describe achievable water quality. Following initial investigation, bioassessment would best be used for long term trend monitoring and in site specific surveys.

Establishment of a bioassessment program requires the identification of the nominal condition of aquatic life in an ecoregion (Odum *et al.*, 1979). This defines a "reference" condition that will enable comparisons within an ecoregion and between other ecoregion drainages. An assessment could be made regarding the health of a site and is indicated through macroinvertebrate community metrics, habitat assessments, land use assessments and identification of probable point- or nonpoint pollution sources. Potential community metrics that would be effective in delineating stress would be functional groups, community similarity, and species abundance. Reference conditions in each ecoregion may be better described by using a unique set of descriptors. These descriptors may be identified through rigorous analysis of existing biological and water quality data sets.

The Ecoregion Concept


Northern Rockies
Puget Lowland
Coast Range
Cascades
Columbia Basin
Eastern Cascades
Blue Mountains
Willamette Valley

Ecoregion Delineation:

1. Land-Surface Form
2. Land Use
3. Soils
4. Potential Natural Vegetation

(Omernik and Gallant 1986)

Figure 1. Delineation of ecoregions in Washington state.

The Ecoregion Concept

An ecoregion is a working geographical unit in which certain features of the landscape show a strong degree of internal homogeneity when compared with other regions. Omernik (1987) defined "ecoregions" in the conterminous United States based on such features as: land surface form, potential natural vegetation, land use, and soil composition (Figure 1). These features influence many of the drainages, chemically and physically, in the same manner throughout a given ecoregion. Of course, there exist overlapping boundaries between ecoregions where the features of each blend together. Omernik and Gallant (1986) identified "generally typical" and "most typical" ecoregional areas for the Pacific Northwest. The generally typical areas are normally found near ecoregion boundaries. It is not uncommon to find drastic changes between ecoregions where most typical areas begin close to a boundary. This situation holds true for many of the northwest's ecoregions. Sharp ecoregional boundary definitions among all the regions do not exist, nor should aquatic communities be expected to drastically change at ecoregion boundaries.

Bioassessment as a Management Tool

Critics of the bioassessment concept often note the complexity and biological variance found in large, regional data sets. This project began by using ecoregions as the initial spatial unit in which replicate sites were located. More than one ecoregion may harbor similar macroinvertebrate populations; in this instance, these may be considered as a single region for purposes of biomonitoring (Hafele pers. comm.). It should be noted that further development of classification schemes following the ecoregion concept are necessary to achieve continuity between sites in similar regions.

Once a spatial classification scheme is established, consideration may be given to defining the influence of pollution sources. Nonpoint sources of pollution are a major concern in maintaining the quality of water resources. NPS pollution usually accumulates slowly over time in a watershed and alters habitat characteristics within the aquatic environment. Water quality monitoring does not always identify NPS pollution in the early stages of impact, but aquatic organism tolerance can serve as an early indicator. Benthic macroinvertebrates are dependent on habitat quality (Minshall 1984), which makes them especially well suited for NPS pollution assessment.

Bioassessment Effort in the State of Washington

A pilot bioassessment network in Washington was established to ultimately supplement conventional surface water quality information and provide greater resolution to existing state criteria that protect water resources and their beneficial uses. Development and use of multivariate statistical analyses and a better understanding of ecosystem structure and function have accelerated the use of bioassessment in a regulatory sense. The regional approach in a bioassessment program provides a systematic framework in addressing the biological component of point and nonpoint source aquatic pollution problems.

A biomonitoring network covering some of Washington's key drainages is a valuable tool used to evaluate the long term goal of preservation and improvement of existing water quality. Coordination with other agencies in the northwest such as the United States Geological Survey (USGS), adherents to the Timber/Fish/Wildlife (TFW) agreement, and local and tribal governments benefit through expansion of available environmental information. Bioassessment is an additional tool by which nonpoint pollution assessments from agricultural and forest activities can be made.

Bioassessment programs using benthic macroinvertebrates in urban watersheds as is done by the Municipality of Metropolitan Seattle (METRO) are an important contribution to the monitoring database. METRO's efforts may be used in defining the macroinvertebrate structure of the urban setting within an ecoregion. This represents a finer resolution in classification of impact in an ecoregion. Satellite projects should be identified to facilitate coordination in early efforts of the bioassessment process to create an efficient program and provide information in a shorter time period.

Phase I-Project Development

Washington State includes an extreme range of conditions within the eight ecoregion types (Cascades to Columbia Basin). This makes individual ecoregion bioassessment a potentially effective tool by nature of unique indicator taxa associations. Bioassessment has initially been implemented in three of the eight ecoregions in Washington (Figure 2). The ecoregions in which sampling has taken place are: the Puget Lowland (Region 2), Cascades (Region 4), and Columbia Basin (Region 10) based on their extreme differences in character (Omernik and Gallant, 1986). Two of the ecoregions

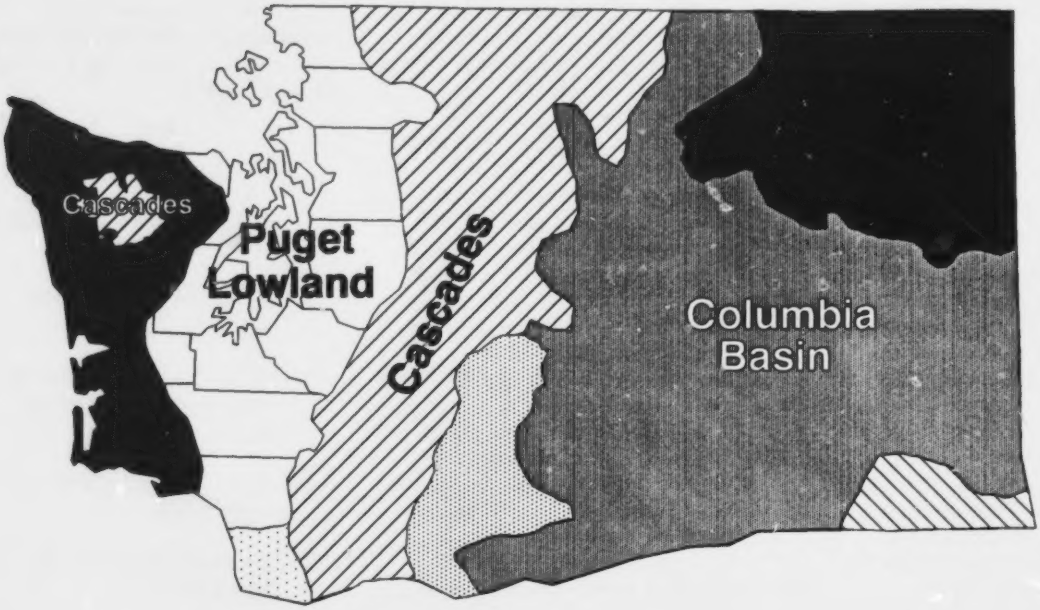


Figure 2. Ecoregions of Washington that were surveyed in the bioassessment pilot project (After Omernik 1987).

selected for this pilot project typically contain forested lands (Cascades, Puget Lowlands). The third ecoregion (Columbia Basin) is predominantly covered by sagebrush and grass populations with forested areas located on the fringes. The Columbia Basin ecoregion offers a contrast in this pilot project that tested the efficacy of bioassessment for drawing distinctions among regions. Obvious differences exist between the Columbia Basin and the Cascades/Puget Lowland ecoregions. This difference served in testing the hypothesis that benthic macroinvertebrate communities can be discerned on a large scale "ecoregional" basis. The Columbia Basin is an ecoregion that may be subject to evaluation for division into subregions. Two distinct vegetational types exist within this region; forested boundaries and a sagebrush/wheatgrass steppe interior. Some ecoregions may better be described on a subregional basis where patches of distinct spatial homogeneity exist within the overall region (Gallant *et al.*, 1989).

The intended use of ecoregion bioassessment as a monitoring tool is that its development will be used to address questions regarding the health of biological communities in similar sized streams during one of the four seasons in a calendar year. Ideally, biocriteria should be developed for each ecoregion in which a reference condition is defined and against which comparisons could be made with biological information from other similar streams. Disturbed stream reaches associated with forest practices or agriculture are identified through biological community descriptors that do not correspond with the reference condition range.

The objectives for Phase I of the Ecoregion Bioassessment pilot project were as follows:

1. Characterize the benthic macroinvertebrate community in generally unimpacted third and fourth order streams of three ecoregions in Washington State (Puget Lowland, Cascades, Columbia Basin). A community reference condition is defined in each of the ecoregions through analysis of information collected at sample sites within an ecoregion.

2. Define the benthic macroinvertebrate reference condition in each season by sampling during optimal segments of time that relay maximal information about the community.

3. Develop a general methods protocol that will be appropriate in applying to ecoregion bioassessment surveys.

METHODS

This pilot project addressed habitat characteristics, benthic macroinvertebrate communities, and surface water quality. Habitat characteristics at each site reflected uniformity within a particular ecoregion in order to optimize characterization of a reference benthic macroinvertebrate community condition. Physical habitat characteristics may have substantial influences on the distribution of benthic macroinvertebrates (Vannote *et al.*, 1980). The water quality information was used as a subset of the environmental information collected at each site and was integrated with the benthic macroinvertebrate community information.

Habitat Survey

Site Determination

Sampling efforts were concentrated in undeveloped and least impacted reaches of streams within an ecoregion as was done with the Ohio Stream Regionalization Project (Whittier *et al.*, 1987). The undeveloped and unimpacted stream reaches were typically the low stress segments of a drainage. The hypothesis was that benthic macroinvertebrate assemblages within an ecoregion were expected to contain similar distributions in drainages with similar habitat types. Monitoring sites were chosen to maximize a situation in which assessment sensitivity was maintained and generalization of information to other streams and stream segments was possible.

Site selection was evaluated by conforming to a set of criteria. These criteria were extracts from a variety of ecoregional investigations and have been identified as effective components in evaluating habitat for site selection. Watershed size and mean annual discharge per unit drainage area have been used as primary descriptors for locating sites (Whittier *et al.*, 1987). The watershed size is based on those most representative of an ecoregion. Mean annual discharge per unit area defines a standardized quantity of water contained by the drainage. A method for watershed ranking has been evaluated whereby land use types are ranked according to severity of potential impact in a receiving stream (Whittier *et al.*, 1987). The rank assigned to a land use is multiplied by percent land use throughout the watershed in order to standardize the expression within a watershed. This method further identifies uniformity among selected reference sites within an ecoregion. The pilot project used unimpacted reference sites. Aerial photographs assisted in identifying existing development, land use, vegetational, and topographic patterns in a drainage.

Site selection for the Ecoregion Bioassessment Pilot Project was a systematic process where a "criteria filter" was developed. The criteria filter used available physical habitat information from sources actively collecting data throughout the state of Washington. Habitat evaluation was ongoing within the United States Forest Service (USFS) (USFS, 1990) boundaries, United States Geological Survey (USGS), and the Timber/Fish/Wildlife Ambient Monitoring Program (T/F/W-AMP) (Ralph, 1990).

The following lists describe criteria for identifying "candidate" sites and then "final" site selection. Continuity among the sites regarding physical characteristics was sought by progressing through the criteria filter.

Candidate Site Criteria:

1. available habitat information existed for the site
2. the drainage was entirely within the ecoregion
3. the drainage was within the "most typical" area of the ecoregion
4. the site was relatively undisturbed
5. the stream was third or fourth order
6. the stream reach was forested

Final Site Criteria:

1. elevation
2. gradient
3. substrate size
4. discharge
5. longitudinal site distribution

Approximately fifty-one sites were identified by satisfying the candidate site criteria throughout the three ecoregions of interest. Existing habitat information was gathered for each site from the three sources previously mentioned. It was possible to obtain information for the candidate site criteria by using USGS topographic maps and the diagram outlining Ecoregions of

Monitoring Site Locations

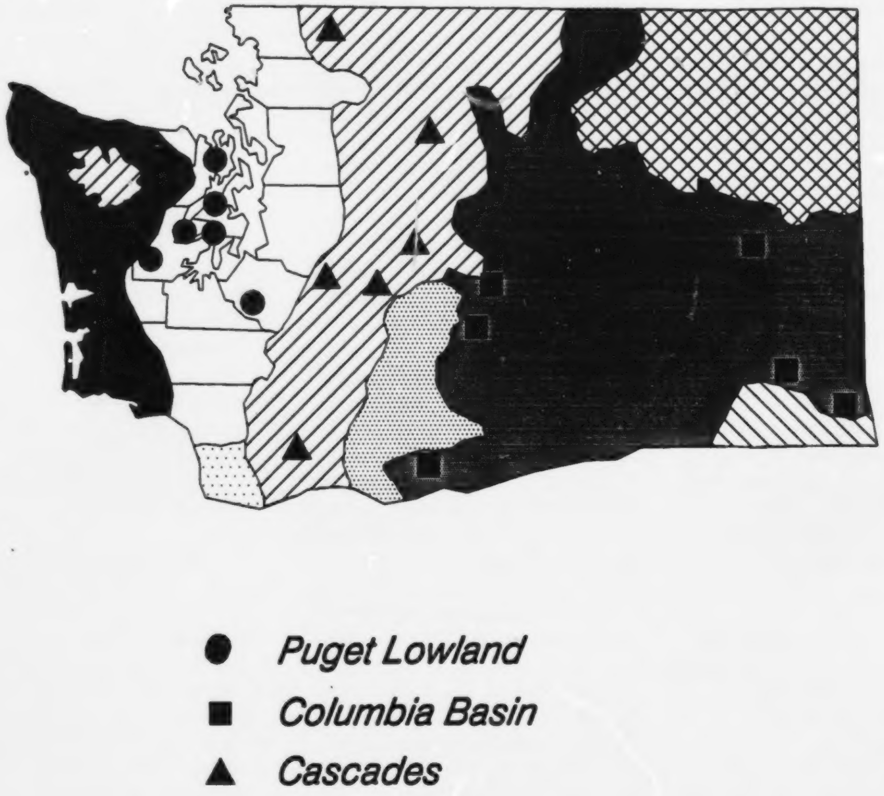

● Puget Lowland
■ Columbia Basin
▲ Cascades

Figure 3. Final site selections for the bioassessment project.

the Pacific Northwest (Omernik and Gallant, 1986). Confirmation of relatively unimpacted streams was accomplished by contacting representatives of the USFS, USGS, and the T/F/W-AMP. Final site selection required the use of site specific habitat information, where available. If specific information was not available for one or more of the final site criteria, an evaluation was performed through an on-site survey. Final monitoring site locations for this project are displayed in Figure 3.

Habitat Evaluation

On-site surveys included observations of physical features at and upstream of the stations. Evaluation was completed using methods developed by the ambient monitoring project (Ralph, 1990) efforts under the T/F/W agreement and the Rapid Bioassessment Protocols (RBP) (Plafkin *et al.* 1989). The RBP method included information regarding: riparian corridor assessment using streamside vegetation, canopy, bank stability, and the presence of buffer zones between the stream and existing land use; instream assessment used substrate composition, water velocity, channel cross-section definition, and cobble embeddedness.

The T/F/W method and RBP method for habitat evaluation each supplemented the other and provided a comprehensive evaluation of physical measurements for both aquatic and terrestrial features. Riffle and run reaches were sampled at all sites in order to maximize the coverage of benthic habitat types (Minshall, 1984). An attempt was made to maintain uniformity of riparian and stream features among sites in the same ecoregion.

Benthic Macroinvertebrates

Benthic Macroinvertebrate Monitoring

Three ecoregions were chosen to implement the biomonitoring project. Six streams selected for habitat characterization in each ecoregion were surveyed for benthic macroinvertebrates. Samples were collected quarterly to obtain seasonal information regarding benthic macroinvertebrate assemblages. Benthic macroinvertebrate populations undergo life cycle changes which influence the presence and absence of populations during different portions of a year. In this case, the reference condition would be unique for each season. Disturbance frequencies such as spates, flood, and drought contain unique seasonal patterns in regions of the state. Disturbance frequency is a major determinant of community structure and functional representation.

The Rapid Bioassessment Protocols (RBP) for benthic macroinvertebrate surveys developed by Plafkin *et al.* (1989) include three levels of complexity. RBP III is the most labor intensive and thorough and was used in this project. The taxonomic level of identification in RBP III is genus or species, which allowed further discrimination of indicator taxa in each ecoregion. RBP II may also be evaluated during a project to determine whether it is adequate for discrimination of ecoregions.

Analysis of Benthic Macroinvertebrate Data

Analysis of the benthic macroinvertebrate data evaluated the use of a number of statistical techniques that either defined underlying population patterns or were descriptive. Three multivariate statistical techniques were implemented in order to determine benthic macroinvertebrate populations that served as indicator taxa and the habitat and water quality characteristics that influenced population distributions in each ecoregion. Detrended Correspondence Analysis and Principal Components Analysis are useful statistical techniques in integrating abundance data sets with data sets containing environmental variables. This approach associates unique benthic macroinvertebrate assemblages with environmental variables that influence their distribution. Identification of unique taxa within each ecoregion was accomplished by using TWINSPAN (Two-Way Indicator Species Analysis) (Hill, 1979); a component of the Cornell Ecology Programs series.

Other techniques that are useful in characterizing the ecoregions are biotic indices. One such method developed for the U.S. Forest Service is the Biotic Condition Index (BCI) (Winget and Mangum 1979). BCI and other indices were evaluated on an ecoregional basis as potential descriptors of benthic macroinvertebrate community characterization.

Box plots of the taxonomic and community descriptors (e.g. diversity) were constructed to graphically illustrate differences in community composition among the ecoregions. This approach was similar to that performed in Ohio (Whittier *et al.*, 1987) and Oregon (Whittier *et al.* 1988). The box plots are an efficient exploratory tool in directing analytical efforts of the benthic macroinvertebrate data.

Water Quality

Water Quality Monitoring

Water samples were collected on a monthly basis at all sites in each ecoregion. Concurrent surface water samples were collected with benthic macroinvertebrate samples and thorough water quality analyses were conducted in three general categories: 1) physical/chemical, 2) nutrients, and 3) ionic strength. The physical/chemical attributes included dissolved oxygen, pH, turbidity, conductivity and temperature. Nutrients of interest were nitrate + nitrite nitrogen, ammonia nitrogen, total nitrogen, total phosphorus, and total organic carbon. Ortho-phosphate was collected on dates corresponding with the benthic macroinvertebrate sample times. Ionic strength was described by alkalinity, calcium, and magnesium concentrations.

Analysis of Water Quality Data

Principal component analysis (PCA) was used to determine:

1) the natural grouping of sample sites, and
2) the water quality variables contributing to seasonal differences among the sites.

PCA explains the variance-covariance structure of a water quality matrix by composition of linear combinations of original variables (Johnson and Wichern 1988). Determination of those environmental factor(s) that accounted for variance in the data matrix reveal information regarding sources of influence. The focus of PCA was to delineate variation in water quality among sites and identify significant characteristic ecoregional differences. PCA was used by Whittier *et al.* (1988) in Oregon and found to be an effective tool in describing the water quality characteristics in ecoregions.

Quality Assurance/Quality Control Procedures

Replication of samples collected in the field and of analyses carried out in the laboratory are integral components of a quality assurance/quality control (QA/QC) program. Replicate samples of benthic macroinvertebrates were collected at each site for determination of sample variation. A cross-check of taxonomic identification was carried out quarterly by an experienced benthic macroinvertebrate biologist. Replication of water quality samples occurred at ten percent of the total number of sites. Habitat assessments were replicated by a second investigator at one site during each quarterly sampling.

Interpretation of results for water quality and benthic macroinvertebrate indicator assemblages were compared to information compiled in Oregon. Two of the ecoregions used in this study (Cascades and Columbia Basin) overlapped with sites located in Oregon and thus provided an excellent opportunity for coordination and data comparison. The assumption was that site selection criteria and macroinvertebrate collection techniques were comparable between the two states' efforts. In the case of ecoregional overlap of political boundaries, cooperative monitoring efforts between states could be proposed for efficiency of information collection and lowered operational costs. Future composition of available ecoregional data would enhance the use of bioassessment as an environmental management tool.

Future Effort and Development

In order to fully develop the ecoregion bioassessment program a second phase of this project is envisioned. Following the establishment of a methods protocol for bioassessment, the next activity would involve surveying impacted sites within the three ecoregions (Puget Lowland, Cascades, Columbia Basin). In addition, the ecoregion sample sites established in the pilot project would continue to be monitored. Comparison between the impacted and unimpacted sites within an ecoregion would be made to assist in developing biocriteria (Figure 4). The biocriteria will reflect the expected biotic potential of an ecoregion and provide an early indication of stress in streams that are surveyed for benthic macroinvertebrates.

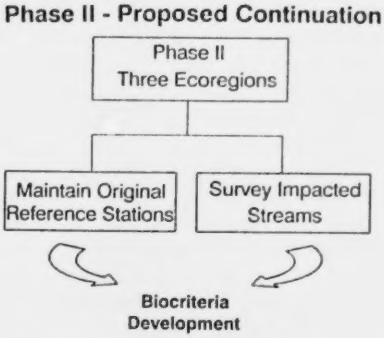


Figure 4. Phase 2: process in development of biocriteria.

SUMMARY

The scope of this bioassessment effort was narrowed to initially identify impacts to aquatic systems resulting from forest practices. The incorporation of biological monitoring with physical and chemical water quality measurements will provide a comprehensive view of timber harvest impacts. Ecoregion bioassessment is a promising monitoring technique based on results from efforts in other states. Information acquired regarding the status of the benthic macroinvertebrate community, water quality and related habitat can be utilized in both routine ambient and intensive investigations and uniquely analyzed to provide a direction in management decisions. These decisions would be based on the destruction of habitat as indicated by indigenous benthic macroinvertebrates and water quality that modifies the benthic habitat. Ecoregions are a convenient geographical unit in which to examine characteristic drainages.

Bioassessment is the next step in constructing a more effective monitoring program of aquatic environments in Washington and is of interest to adjacent states. The pilot project for ecoregion bioassessment addresses the missing monitoring component of surface water investigations presently conducted in this state. This additional step in our effort to preserve and enhance our freshwater resources will be reflected in better management decisions and fewer problems requiring long-term reclamation of impacted aquatic systems.

ACKNOWLEDGEMENT

The Timber/Fish/Wildlife Program funded this project for the purposes of better defining forest harvest impacts on aquatic life. T/F/W has demonstrated foresight in a variety of funded projects which will enable a better understanding of forest practice impacts and also encourage enhancement of existing natural forest resources.

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Monitoring the Yakima River Basin

Stuart McKenzie
U.S. Geological Survey

ABSTRACT

In 1986, the U.S. Geological Survey began the NAWQA (National Water-Quality Assessment) Program to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to provide a sound understanding of the natural and human fators that affect the quality of these resources. The pilot study in the Yakima River Basin, Washington is one of the four surface-water projects initiated in 1986.

The objectives of this pilot study are to use existing data and iteratively add new data to (1) describe spatial and temporal changes in water-quality conditions; and (2) relate observed water-quality conditions to sources and causes, transport, fate , and where possible, to effects from contaminants.

Bioassessments are being conducted to increase our understanding of relations between biota and water chemistry. Specific objectives of the bioassessments include (1) quantifying populations of algae, benthic invertebrates, and fish; (2) determining the presence or absence of toxic compounds in biota as indicators of water-quality conditions; and (3) quantitatively describing habitat as a basis for measuring and evaluating long-term changes.

Questions for Stuart McKenzie

Q. To what extent are you looking at currently used pesticides vs. historically used ones?

A. We started by going to the county agents in each of 3 counties and asked them for a list of all the pesticides currently being used. List amounted to 60 or 70 major ones. Then we sat down with the handbooks of organic chemistry and handbooks of agricultural chemicals and looked to see which ones were toxic, which were persistent in the environment, and finally, with an analyst, which ones can you find with the available methods. You almost have to pre-select which ones you are going to go after in order to have quality control at the analytical end. It's fine to say, "we are going to look for everything.", but for the analyst, that's a major problem.

Q. Were you only looking for the parent compounds?

A. No, we were looking for the breakdown products as well. But for the analyst, that's a major problem. He can't identify those breakdown products as well. You run into that with the triazines. And also, we are just getting the capability of a low enough detection level so that we can sort out what's there and what's not there. We have some new research techniques that we are trying out, that I will show you later.

Q. What would you say if you were hazarding a guess as to the source of the DDT. [Elevated levels were reported compared to other sites in the nation.]

A. Four or five hypotheses: One of the slides shows that in the Yakima Basin about 40% of the DDT plus metabolites of DDT is still DDT. Across the nation, it's 10% to 30%. So, why is there so much DDT in the Yakima Basin? One hypothesis is: in the arid dry climate over the Yakima, it just doesn't break down as fast. Second, there is so much that it is inhibiting the organisms that break it down from acting. A third, that they are still using DDT. A fourth, that the instrumentation, because of contamination with DDT (an analytical chemist told me this) through use, gives incorrect, abnormally low readings in the other sites across the country, so that ours is a more correct data set. Frankly, I can't separate out which of those are correct. I tend to think that arid climate and analytical problems are the major component.

Q. Can global transport be a part of it?

A. It could be, but I don't think so because we went to an area where, if it was global transport it should have showed up, high in the Cascades, and we didn't find it. It's interesting, however, that when we looked at it in fish from that environment, we did find it above the limit of detection, so it is still there.

Strategy for Pesticide Monitoring in the Yakima River Basin Using Tissue Analysis

Dr. J. Kent Crawford
U.S. Geological Survey

ABSTRACT

Tissue analysis will be used in the National Water Quality Assessment (NAWQA) Program primarily to document the occurrence, distribution, and trends of pesticides in tissues in study units (river basins). Target compounds are those that strongly concentrate in biological tissues, but that are not readily metabolized. These include 46 compounds having bioconcentration factors greater than 300 and which are known to be toxic. Target organisms are those which are widespread in the study unit and are expected to be readily found in many other basins across the nation. The Asiatic clam, Corbicula fluminea, *is the primary target organism.*

In the pilot NAWQA study for the Yakima River basin, 22 pesticides from the target list of 46 pesticides, were analyzed for in tissue samples of fish, mollusks, and plants collected in 1989. Twelve different organochlorine compounds were detected in the samples. DDT or its breakdown products were detected in samples from each of the 19 sites sampled. Dieldrin was detected in samples from 15 of the 19 sampling sites. Dicofol was detected in tissue samples from eight sampling locations. Chlordane and trans-nonachlor were detected at six locations. Toxaphene was detected at four sites and PCB's were detected in tissues from three sites. The maximum concentrations were from agricultural drains entering the Yakima River. In general, sites farther downstream on the main stem of the River had greater concentrations than upstream sites on the main stem. Samples from headwater reference sites had the lowest concentrations.

The analysis of pesticides in tissues, water, and sediments, provides multiple lines of evidence for evaluating the status of a water body. Therefore, tissue analysis should be considered as part of any water-quality monitoring strategy.

Questions for Ken Crawford:

Q. (Bill Cooper) Question about interpreting that trend from the 1st order streams and the 5th order streams. There is also a big shift in carbon dynamics. In the 1st order stream it is almost all leaf litter, the discharge is fine particulate material because of the shredder component. In the low level streams, it is mostly fine particulate, detritus food chains. That would explain the larger accumulation in fish. They make half their diet of {predatory?} insects. The whole carbon dynamics are different and both dieldrin and DDT are going to be adsorbed on that carbon. I wonder if you couldn't explain the distribution of DDT in your sample on that basis?

A. an interesting concept, I wouldn't want to touch it.

(tape ends)

Q. [unintelligible, but refers to comparing his data with another data set or sets.]

A. Well, I haven't looked at the NCBP data (for this area?). That's the only other long term data set we have for tissues. They are showing declines all across the US for DDT's. Are you familiar with the National Contaminant Biomonitoring Program of the Fish and Wildlife Service? It's been in operation since the mid 1960's. It's the only one that's been underway continuously for that long. They are showing declines across the board in many of the chlorinated pesticides that we are monitoring. The one year of data that you've seen here is all that we have. Washington DOE has done some work with DDT's, and I think tthat they are also reporting declines in DDT's in biological organisms.

Q. Do you think that, for example the differences in feeding habits between trout and sunfish may have some bearing?

A. Sure, absolutely! That's why our first priority is bottom feeding fish. We'd like to get carp, suckers, maybe even catfish, bullheads.

Q. Maybe that's why you're not getting so much upstream . . . .

A. Maybe, but we are also looking at whitefish downstream, and they are showing increased levels of these contaminants.

A Strategy for Monitoring Contemporary Pesticides Entering Estuarine Habitats[1]

Michael Rylko
EPA 10th Region, Office of Coastal Waters

Based on determinations of contemporary pesticide use in the Puget Sound basin, a reconnaissance sampling effort was conducted to assess pesticide migration into estuarine habitats. Both whole-water and sediment samples were collected. Analytical detection limits for both sediment and water samples were in the low parts per billion range. Resulting data were intended to document possible discharges of pesticides to Puget Sound estuaries under conditions that would favor pesticide transport. The data collection strategy was not specifically designed to determine loadings to Puget Sound. However, flow-proportioned sampling procedures were used and estimates of discharge were calculated at time of sample collection.

Five pesticides were detected in water samples: diazinon; 2,4 dichlorophenoxyacetic acid (2,4-D); dicamba; bromacil; and diuron. Four pesticides were detected in sediment samples: dichlobenil, DDT and its breakdown products (DDE and DDD), endosulfan, and pentachlorophenol.

Questions for Michael Rylko

Q. Mike, you had a slide where you showed bottom material and you had whole water samples, what were your units of concentration?

A. Those were all parts per billion.

Q. Even the bottom sediment?

A. Yes.

Q. That last slide where you showed the Dicamba in the Nisqually and Skagit, did you only show the sediment load?

A. yes, '88 data was wholly sediment. That's the only data we had tabulated, and I showed it just to show you that there is both spatial and temporal variability.

Q. The emphasis on one event is good because you can get fresh runoff from the application. It is problematic because the flood mobilizes material that was in the river before.

A. This is a very interesting point. During one of our false starts we had a team that was one and a half hour's drive away. They called and said, it's not happening. We said, take the sample anyway. And interestingly enough, we found things that we did not expect. We got as many that day as we did with the event afterwards. The concentrations did not vary much, but the compounds that we found certainly did, and those were probably 30 days apart.

Q. At the beginning of your talk you referred to [salmon?] (yeah), did you think any more about it?

A. No, it was only a scenario to help us to think about the kind of monitoring scheme we wanted to develop, because that was the kind of issue we wanted to apply our data to.

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[1] The report of the results of this survey: **Draft Report, 1990 Puget Sound Pesticide Reconnaissance Survey**, and results of prior surveys are available from Michael Rylko, Office of Puget Sound (mailstop WD-139), USEPA Region 10, 1200 6th Avenue, Seattle, WA 98101.

Session II. Theoretical Studies: Dan McKenzie, Chair

A. Indicator and biomarker development.

Biomonitoring: Myth or Miracle?

Wayne G. Landis
Institute of Environmental Toxicology and Chemistry
(article)

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Lichens as Biological Markers

Roger Rosentreter
U S Department of the Interior
Bureau of Land Management
(article)

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Bees as Biomonitors for Ecological Risk Assessments

Jerry J. Bromenshenk
Division of Biological Science, University of Montana
(abstract)

B. Methods of Risk Assessment

Applying Risk Assessment to Ecological Communities

William Cooper
Chairman, Department of Zoology, Michigan State University
(transcript)

C. Modelling of Community Responses to Hazards

Monitoring Pesticide Exposure and Impact
in Wildlife Inhabiting Agroecosystems

Michael J. Hooper
The Institute of Wildlife and Environmental Toxicology
Clemson University
(abstract)

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A Model for Describing Community Change

Geoffrey Matthews
Computer Science Department
and
Robin Matthews
Huxley College of Environmental Studies
both authors at
Western Washington University
(article)

Biomonitoring: Myth or Miracle?

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ABSTRACT:

Biomonitoring is a term that includes a variety of biochemical physiological and ecological evaluations designed to determine the health of a particular system. Two separate functions generally are placed in the generic category of biomonitoring. First is the determination of environmental concentrations using analytical or biochemical determinations of biological tissue. Second, effects are monitored that provide an indication of exposure and toxic insult at various levels of biological organization. Importantly, methodologies labeled as biomonitoring are usually designed to look at only one aspect of a toxicant impact upon an ecosystem or species. Debate occurs as to what real significance can be placed upon the inhibition of a particular enzyme or the loss of species diversity. Part of the debate is due to our lack of understanding of the functions that describe the transformation of a chemical structure into an impact at the populational and ecosystem levels. This overview delineates the common biomonitoring techniques in relationship to the path from toxicant input to ecosystem effect. Each level is critiqued as to its strengths and weaknesses. Finally, recommendations for further discussion and research are put forth.

INTRODUCTION

Biomonitoring is a term with many meanings depending upon the application and the regulatory framework. This paper attempts to summarize the initial discussion paper and incorporate aspects of the dialogue of the working group at the recently held Pesticide Biomonitoring Conference held December 11-12, 1990 in Corvallis, OR.

Biomonitoring is a term that implies a biological system is employed in some way for the health evaluation of an ecosystem. In general, biomonitoring programs fall into two categories: exposure and effects. Many of the traditional monitoring programs involve the analytical measurement of a target compound with the tissue of a sampled organism. The examination of pesticide residues in fish tissues or PCBs in terrestrial mammals and birds are examples of this application of biomonitoring. Effects monitoring looks at various levels of biological organization attempting to evaluate the health of the biological community in the field. Generically, effects monitoring allows a toxicologist to perform an evaluation without an analytical determination of any particular chemical concentration. Synergistic and antagonistic interactions within complex mixtures are integrated into the biomonitoring response.

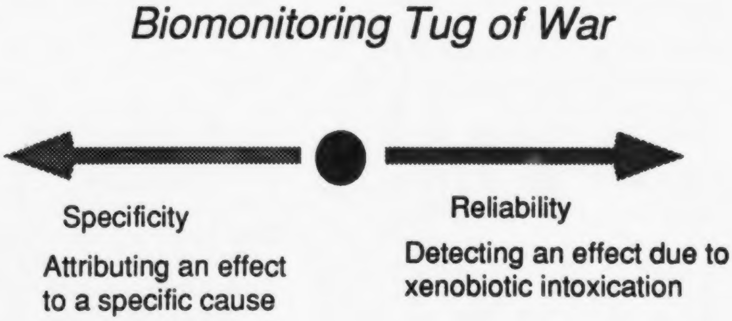
Biomonitoring Tug of War
Specificity
Attributing an effect to a specific cause
Reliability
Detecting an effect due to xenobiotic intoxication

Figure 1. The Tug of War in Biomonitoring. An organismal or community structure monitoring system may pick up a variety of effects but lack the ability to determine the precise cause. On the other hand, a specific test such as looking at the inhibition of a particular enzyme system, may be very specific but completely miss other modes of action.

In effects testing there is the problem of balancing specificity with reliability (Figure 1). Specificity is important since it is crucial to know and understand the causal factors in order to dictate management or clean up methods. However, an increase in specificity generally decreases the reliability of the system in seeing an impact at the population or

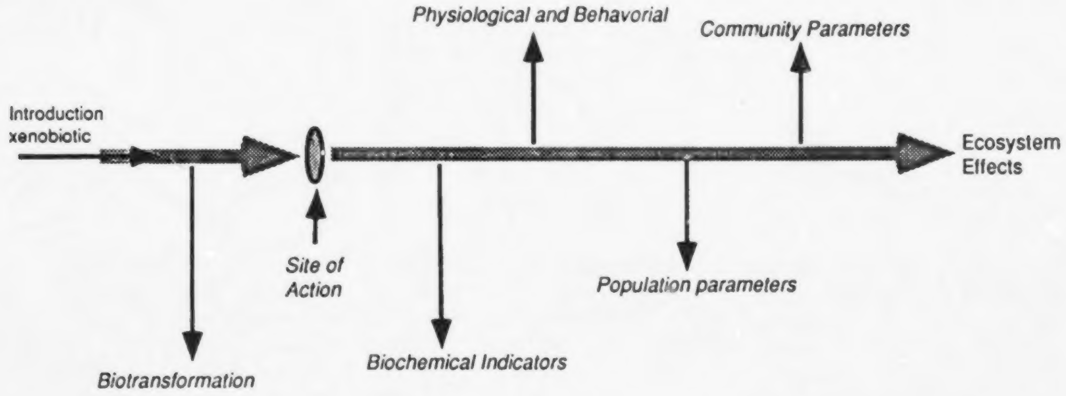

Figure 2. Levels available for biomonitoring. Biomonitoring effectively falls into two categories, (1) transport and transformation of the xenobiotic before interaction with the site of action; and (2) impacts on the biology of the organism and its community after the site of action has been altered by the compound. Technologies are available to examine each level or interaction and impact.

community levels. This decrease in reliability is simply due to the numerous modes of action that exist and that are exhibited by a potential chemical contaminant. A balancing act is usually done where certain materials are specified by experience or regulation, narrowing the choice of materials and impacts being monitored.

There is a continuum of monitoring points along the path that an effect on an ecosystem takes from introduction of a xenobiotic to the biosphere to the final serious effects (Figure 2). Techniques are available for monitoring at each level although they are not uniform for each class of toxicant. If we as a scientific community could write appropriate functions that would describe the transfer of an effect from its interaction with a specific receptor to the effects seen at the community level, it would certainly be easier to choose a biomonitoring strategy. Unfortunately, we understood only in the poorest terms how the impacts seen at the population and community levels are propagated from molecular interactions.

Given this background however, it is possible to outline the current levels of biomonitoring:

Bioaccumulation/
Biotransformation/
Biodegradation
Site of Action
Biochemical Monitoring
Physiological and Behavioral
Populational Parameters
Community Parameters
Ecosystem Effects

Many of these levels of effects can be examined using organisms native to the particular environment or planted by the researcher. There is an interesting trade-off in which to use. The naturally occurring organism represents the population and the ecological community that is under surveillance. However, there is no control over the genetic background of the observed population and little is usually known about the native species from a toxicological viewpoint. Introduced organisms, either placed by the researcher or enticed by the creation of habitat have the advantage of a database and some control over the source. However, questions dealing with the realism of the situation and the alteration of the habitat to support the introduced species can be raised.

The remainder of this discussion will provide examples of monitoring systems at each organizational level. Effects at virtually all levels of organization can be observed using native or introduced organisms.

Bioaccumulation/ Biotransformation/ Biodegradation

A great deal can occur to the introduced pesticide or other xenobiotic from its introduction to the environment to its interaction at the site of action. Bioaccumulation often occurs with lipophilic materials. Tissues or the entire organism can be analyzed for the presence of compounds such as PCBs and halogenated organic pesticides. Often the biotransformation and degradation products can be detected, for example, DDE is often an indication of exposure to DDT in the past. Although analytical chemistry has been the mainstay of this aspect of biomonitoring other methods may become useful. With the advent of DNA probes it may even be possible to use the presence of certain degradative plasmids and specific gene sequences as indications of past and current exposure to toxic xenobiotics. Biosensors are a new tool that may also hold promise as new analytical tools. In this new class of sensors a biological entity such as the receptor molecule or an antibody for a particular xenobiotic is bound to an appropriate electronic sensor. A signal can then be produced as the material bound to the chip interacts with the toxicant.

Site of Action

The site at which the xenobiotic interacts with the organism is also a potential tool. The site of action may be the nucleic acids, specific proteins within nerve synapses or present within the cellular membrane, or it can be very nonspecific. Narcosis may affect the organism not by interaction with a particular key molecule, but by changing the characteristics of the cell membrane.

Biochemical Indicators

A great deal of research has recently occurred on the development of indicators to determine the exposure and effects of toxicants. Versteeg, Grany and Giesy (1988) have recently reviewed the utilization of biochemical measures for aquatic organisms. Often these biochemical indicators are labeled biomarkers. The following is only a brief synopsis of this growing field.

The inhibition of acetylcholinesterase in plasma or brain tissue has been investigated extensively for a variety of organisms, from birds to fish. Numerous acetylcholinesterase inhibitors are used in agricultural activities making this marker especially attractive. Unfortunately, natural variation in the levels of acetylcholinesterase activity has not been as well documented as methods in determining inhibition. Recent research by Hooper (abstract, this volume) has started to tie natural variation to the differences seen upon exposure to an acetylcholinesterase inhibitor.

Stress proteins are another potential marker. As far as can be determined, they are universal (Bradly 1990). Stress proteins are easily detected and the rate of synthesis and the type of stress protein produced can provide an indication of the level of stress. Unfortunately, many stressors other than chemicals initiate the production of stress proteins. The presence of stress proteins may not signal impact by a pollutant.

DNA adducts and strand breakage can be used as indicators of genotoxic materials (Shugart 1990). One advantage to these methods is that the active site can be examined for a variety of organisms. The methodologies are proven and can be used virtually regardless of species. However, damage to the DNA only provides a broad classification as to the type of toxicant. In addition, the study of the normal variation and damage to DNA in unpolluted environments has just begun.

Immunological suppression by xenobiotics could have subtle but important impacts on natural populations. Invertebrates and other organisms have a variety of immunological responses that can be examined in the laboratory setting from field collections. The immunological responses of bivalves in some ways are similar to vertebrate systems and can be suppressed or activated by various toxicants (Anderson 1975, Anderson, et al, 1981). Mammals and birds have well documented immunological responses although the impacts of pollutants are not well understood. Considering the importance to the organism, immunological responses could be very valuable at assessing the health of an ecosystem at the populational level.

Physiological and Behavioral Indicators

Physiological and behavioral indicators of impact within a population are the classical means by which the health of populations are assessed. The major drawback has been the extrapolation of these factors based upon the health of an individual organism, attributing the damage to a particular pollutant and extrapolating this to the populational level.

Cytogenetic examination of meiotic and mitotic cells can reveal damage to genetic components of the organism. Chromosomal breakage, micronuclei, and various trisomies can be detected microscopically. Few organisms, however, have the requisite chromosomal maps to accurately score more subtle type of damage. Properly developed, cytogenetic examinations may prove to be powerful and sensitive indicators of environmental contamination for certain classes of materials.

Lesions and necrosis in tissues have been the cornerstone of much environmental pathology (Meyers and Hindricks 1985). Gills are sensitive tissues and often reflect the presence of irritant materials. In addition, damage to the gills has an obvious and direct impact upon the health of the organism. Related to the detection of lesions are those that are tumorigenic. Tumors in fish, especially flatfish, have been extensively studied as indicators of oncogenic materials in marine sediments. Oncogenesis has also been extensively studied in *Medaka* and trout as a means of determining the pathways responsible for tumor development. Development of tumors in fish more commonly found in natural communities should follow similar mechanisms. As with many indicators that may be used in the process of biomonitoring, relating the effect of tumor development to the health and reproduction of a wild population has not been as closely examined as the endpoint.

Reproductive success is certainly another measure of the health of an organism and is the principal indicator of the organism's Darwinian fitness. In a laboratory situation, it certainly is possible to measure fecundity and the success of offspring in their maturation. In nature these parameters may be very difficult to measure accurately. Many factors other than pollution can lead to poor reproductive success. Secondary effects, such as the impact of habitat loss on zooplankton populations essential for fry feeding, will be seen in the depression or elimination of the young age classes.

Mortality is certainly easy to assay on the individual organism, however, it is of little use as a monitoring tool. Macroinvertebrates, such as bivalves and cnidaria, can be examined and since they are relatively sessile, the mortality can be attributed to a factor in the immediate environment. Fish being mobile can die due to exposure kilometers away or because of multiple intoxications during their migrations. Also, by the time the fish are dying, the other levels of the ecosystem are in a sad state.

Although not biomonitoring in the sense of sampling organisms from a particular habitat, the use of the cough response and ventilatory rate of fish has been a promising system for the prevention of environmental contamination (van der Schalie 1986, van der Schalie et al 1988). Pioneered at Virginia Polytechnic Institute and State University, the measurement of the ventilatory rate of fish using electrodes to pick up the muscular contractions of the operculum has been brought to a very high stage of refinement. It is now possible to continually monitor water quality as perceived by the test organisms with a desktop computer analysis system at relatively low cost.

Population Parameters

A variety of endpoints have been developed using the number and structure of a population to indicate stress. Population numbers or density have been widely used for plant, animal and microbial populations in spite of the problems in mark recapture and other sampling strategies. Since younger life stages are considered to be more sensitive to a variety of pollutants, shifts in age structure to an older population may indicate stress. Unfortunately, as populations mature, age determination or comparison becomes difficult. In addition, cycles in age structure and population size occur due to the inherent properties of the age structure of the population and predator-prey interactions. Crashes in populations such as that of the striped bass in the Chesapeake Bay do occur and certainly are observed. A crash often does not lend itself to an easy cause-effect relationship making mitigation strategies difficult to create.

The determination of alterations in genetic structure, that is the frequency of certain marker alleles has become increasingly popular. The technology of gel electrophoresis has made this a seemingly easy procedure. Population geneticists have long used this method to observe alterations in gene frequencies in populations of bacteria, protozoa, plants, various vertebrates and the famous *Drosophila*. The largest drawback in this method is ascribing differential sensitivities to the genotypes in question. Usually a marker is used that demonstrates heterogeneity within a particular species. Toxicity tests can be performed to provide relative sensitivities. However, the genes that have been looked at to date are not genes controlling xenobiotic metabolism, but are genes that have some other physiological function and act as a marker for the remainder of the genes within a particular linkage group. Although with some problems, this method does promise to provide both populational and biochemical data that may prove useful in certain circumstances.

Alterations in the competitive abilities of organisms can be an indication of pollution. Obviously, bacteria that can use a xenobiotic as a carbon or other nutrient source, or that can detoxify a material have a competitive advantage, all other factors being equal. Xenobiotics may also enhance species diversity if a particularly competitive species is more sensitive to a particular toxicant. These effects may lead to an increase in plant or algal diversity after the application of a toxicant.

Community Parameters

The structure of biological communities has always been a commonly used indicator of stress in a biological community. Early studies on cultural eutrophication emphasized the impacts of pollution as they altered the species composition and energy flow of aquatic ecosystems. Various biological indices have been developed to judge the health of ecosystems by measuring aspects of the invertebrate, fish or plant populations. Perhaps the largest drawback is the effort necessary to accurately determine the structure of ecosystems and to understand pollution induced effects from normal successional changes. There is also the temptation to reduce the data to a single index or other parameter that eliminates the dynamics and stochastic properties of the community.

One of the most widely used indexes of community structure has been species diversity. Many measures for diversity are used, from such elementary forms as species number to measures based on information theory. A decrease in species diversity is usually taken as an indication of stress or impact upon a particular ecosystem. Diversity as an index, however, hides the dynamic nature of the system and the effects of island biogeography and seasonal state. Also as demonstrated in microcosm experiments (Landis et al 1988a, 1988b, 1989), diversity is often insensitive to toxicant impacts.

Related to diversity is the notion of static and dynamic stability in ecosystems. Traditional dogma stated that diverse ecosystems were more stable and therefore healthier than less rich ecosystems. The work in the early seventies of May (1974) did much to question these almost unquestionable assumptions about properties of ecosystems. I certainly do not doubt the importance of biological diversity, but diversity itself may be an indication of the longevity and size of the habitat rather than the inherent properties of the ecosystem. Rarely are basic principals such as island biogeography incorporated into comparisons of species diversity when assessments of community health are made. Diversity should be examined closely as to its worth in determining xenobiotic impacts upon biological communities.

Safety Factor Applied to Biomonitoring

$$\text{Biomonitoring Efficacy} = \frac{\text{Concentration at which undersirable effects occur}}{\text{Concentration at which biomonitoring system registers an impact above background}}$$

Figure 3. Efficacy of a Biomonitoring Strategy. When designing a biomonitoring strategy it is important to have some calculation of how useful the system is. In applying the idea of a safety factor or ratio to biomonitoring it could simply be a comparison of the concentration of the pollutant that causes an effect in the biomonitoring system as opposed to the concentration that causes substantial impact.

Ecosystem Effects

Alterations in the species composition and metabolism of an ecosystem are the most dramatic impacts that can be observed. Acid precipitation has been documented to cause dramatic alterations in both aquatic and terrestrial ecosystems. Introduction of nutrients certainly increase the rate of eutrophication. As a part of a biomonitoring strategy, these types of effects are not of particular interest except from the point of view of documenting final effects. Hopefully, a competent biomonitoring strategy would prevent this type of wholesale destruction.

Synthesis

Many methods for the biomonitoring of both terrestrial and aquatic systems exist. None is perfect. Methods emphasizing molecular approaches certainly are precise, yet have a long leap to the description of ecosystem health. Population, community and ecosystem level approaches may not be powerful enough due to lack of sampling resources or methodology to detect all but the most obvious effects. Even the description of a healthy ecosystem sometimes is difficult considering the fact that even the most remote habitats have been subject to contamination. Obviously a concerted strategy is necessary to perform an adequate job of biomonitoring in any system. I would like to propose a criterion of biomonitoring efficacy that could be used to judge the utility of a biomonitoring scheme.

Figure 3 is a synopsis of this efficacy factor. It is simply the concentration at which a real effect can be detected by a biomonitoring strategy compared to the concentration that caused damage to the system under protection. Obviously, a ratio of 1 is of no practical use. Biochemical methods may occasionally provide large factors but produce an inordinate amount of false alarms and negatives, reducing the utility of the test. Such a factor may however, provide some estimate of protection and an idea of the point of diminishing returns.

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Questions for Wayne Landis

Q. What does it mean when you get tissue concentrations of, I'll use the example of PCB's. What does it mean when you go out monitor and get all those numbers, at that level?

A. Why did we spend all that money? I guess it's because we thought it might be important to human health, not because of any risk [ecological?]. Have we looked at these other parameters. The only thing I know of is that the organochlorines may be immunosuppressors, and the effects may not be due to straight toxicology, but because all of a sudden you have a pandemic running through the population because of immunosuppression. Those are the kinds of things that might be happening, but just because PCB is there, without having any effect, I'm not so sure it does tell you very much. Also, chemistry is only telling you that what you are looking for is there, things that you don't see may be the things that are important. That's the good thing about biomonitoring, that hopefully you will pick up the parameters about the things that you don't necessarily see.

Q. When you go out and measure body burdens, you know what is out there, but when you measure, lets say, cholinesterase inhibition, how, as a regulator, can you say there's an effect, right, but you don't know the source of that. So how do I correct the problem?

A. That's a good question! Acetylcholinesterase - I have good days and bad days when I think about acetylcholinesterase inhibition. Sometimes I say, heres a molecule, you can say, "Yes, it's being inhibited". But I know for a fact most of the people here could walk around with 30 to 40% of the cholinesterase in their blood plasma inhibited, and you'd never know the difference. Not that this is a particularly tense group of people! But ecologically, that's just the way it is.

Q. We do bio-monitoring to see whether something is just tipping over the side. A lot of times when you are doing large-scale screening for contaminants, be it O-C's or metals, without knowing what kinds of biochemical end-points are being affected, The biochemical end-point can be that middle point between contaminant levels and your population or ecosystem effects, and I think that once you get a biochemical end-point responding, you are starting tip the scales towards an impact on the species.

A. The trouble with that is that we don't understand that function, the one before the chemical gets to the site, and the one after it leaves. If we knew those functions, we wouldn't be arguing, we'd know. Those functions are largely f(X). When you don't know what X is!

Biomonitoring Workshop

Wayne Landis, Chair

[Note: "Q." denotes audience comment; the speaker's name is given if identified. "A." denotes comment from chair. This is an edited transcript.]

A. There may have been questions that were not answered earlier today; there wasn't much time for questions. We will have some round table discussion, and then come up with some odds and ends that we can give the other half of this group. There's not supposed to be a whole lot of structure. That's what Mike said. I think we should examine at least research areas in order to make biomonitoring be a better methodology, and to tie it in to risk assessment. If anything I said in my talk this morning got anyone's adrenalin flowing, or whatever, I'd be more than willing to go into it.

Q. Rice: you and Crawford alluded to what I call the "organochloride mentality", which many land managers and others hold. It is so strongly focussed on the behavioral experience, and environmental fate of organochlorides, with their high lipid solubility and their likely persistence, and the whole process is driven by that organochloride mentality, when in practice, in pesticides we go past organophosphates, and even a little bit past the carbamates, which have quite different properties in terms of environmental fate. The worst of it is that the people in the chemical industry might argue that the development of more specific compounds, less persistent compounds, and less mobile compounds is inhibited by the regulatory climate which we inherited from the organochloride experience. I'd like to say that this blocks us as researchers who look at biomonitoring approaches, that we address the types of compounds and current use patterns that are in effect. It's interesting to look at the distribution of DDT in (?) bodies 20 years after the chemical has been banned in North America, but I don't think it will lead us to address the problems of the new generation.

Q. I've seen that graduate students are so imbued with the DDT mentality that it is almost impossible to break them out of it.

Q. Westerdahl: In my discussions with the chemical industry, they have gone beyond the older chemistries and are embarking on new ones, and the thing that is impeding them in obtaining registration is the length of time and cost involved in obtaining registration. $50 to $75 million to get registered. And despite the length of time it takes them to get registered, they have such a short period of time in which to recoup their costs, that, except for the largest crop uses or pests by areas, they are beginning to slow down their development of new products. So they are under the gun, they are looking for ways to develop new, environmentally safe compounds, and putting out less compound and being as effective or more effective, but they are also tied into the regulatory requirements. So you are seeing a slowdown in the development of new chemicals, but at the same time you are seeing an increase in the rate of development of new methods of application, at lower rates, better formulations, improved carriers, that target the desired pest. I think that when we think of monitoring in the future we are going to have to take into account the mentality of the industry that we are looking at, both from the active ingredient standpoint and the method of application and carrier used. So, the ways of sampling used in the past may not be appropriate for the future.

Q. I think we need to define what our goals are for biomonitoring. Two things came up in discussion this morning. One of those goals is to monitor all of the kinds of chemicals and see what's there, and the other is to use biomonitoring, and see what are the ecological effects of what is there. Maybe we can talk about how those two goals can get integrated, or do they have to be integrated. Or, which one should be looked at first. I'd like to hear some discussion about those two disparate goals, and do people see them as disparate.

A. I also think that ties right into this: if you really understand what you want from biomonitoring, this will fall out. If you are monitoring for pyrethroids, you'll have to use new methods, but you still, I should think your goals will be somewhat similar. You definitely need to define those goals. I don't know if the chemistry is as important to me as the effects. We must ask, have we done a good job. If we have done a good job, it's because our methods are good.

Q. We want to identify the target population. If we want to measure what may happen to a target organism, we may have to monitor at some other level in the food chain. A functional grouping that may be affecting that, earlier on, so that we can tell quicker the status and trend of that organism. Too often, we may be oriented toward monitoring the target species rather than the functional organisms that may be more important as far as what the impact may be on the longer term scale. So there are a lot of questions that are important as far as biomonitoring is concerned. Are we looking at status now, are we trying to predict what the immediate effects on targets are, or are we trying to predict the long-term effects on the targets and/or the selected non-targets.

Q. We are talking about a lot of different pesticides. I hear a lot of people talking about pesticides, and what they are really talking abut is insecticides. My particular need is to look at the effects of herbicides, particularly in forestry environments. I would like to see coming out of this group, new methods of looking not only at new insecticides but also at currently used herbicides.

Q. The problem is that the methods that have been developed to look at insecticides may not be the best ones to look at herbicides, and I'm thinking particularly about the DDT situation, which we know bio-accumulates very strongly, while the herbicides are less bio-accumulative.

Q. But if you are looking at effects, you need analytical methods. Do you need to measure residues, or can you look at effects, just monitor trends in effects without the residue data? Do you absolutely need the residue data, or are there ways to measure correlations from the effects to the causes with use patterns?

Q. From a management perspective, you have to know what dose you must limit, to keep those effects from manifesting themselves in the system.

Q. Compounding the problem, EPA and the states have done a lot of work developing criteria on the aquatic environment and water quality criteria, and none of that has been focussed on herbicides. It's all been insecticides.

Q. A point about herbicides. The great majority of pesticides applied in the U.S. are herbicides, and they are applied on corn and soybeans, and most of the insecticides are applied to cotton. And with the advent of the sulfano-ureas, the newer herbicides are not a mammalian toxicity problem at all. They are less toxic than table salt. They are extremely toxic to plants, however, and they could come into natural systems, for instance by drift and re-volatilization from fields, and potentially could raise problems. Not only could they raise problems in the plant communities, but there are secondary effects, that probably would raise more concern, if we start altering food availability for higher organisms.

Q. I was just wondering, two ideas, one is looking at ecosystems function, and effects on function, and other people are also developing new techniques, techniques for herbicides as opposed to classical pesticides. Somehow, I don't think those ideas are all that separate, because in order to observe effects we have to develop new techniques, but to develop those techniques we have to know what effects we want when we start looking at it. Now lets think about (?) effects, and how they might be different, and the thinks you are looking at may be different, but I don't think they will be all that different, because you are looking at key ecosystem functions, and they won't be that different, no matter what the xenobiotic you are applying. And so you may come up with a scheme that is applicable no matter whether you are looking at an herbicide, rodenticide, insecticide or whatever, and also a way of breaking it down, perhaps more important than things you can't measure, such as, is it an herbicide, rodenticide, or whatever. But I don't hear the difference that much because we are starting to hear effects a lot, and so what if you have luciferase in a test plate, so what?

Q. In some of the bird work the indirect effect of pesticides on game birds is through the eradication with herbicides of the weeds that supported most of the insects, so what you are talking about is not particularly residues, perhaps, but insect densities so this gets into a real complicated situation. It's not like going out and sampling a tissue , it's more complicated.

Q. I think the agro-ecosystem in the midwest, for example, that supports 60% of the world is very different than the system on the Indian homelands of southwestern Idaho. So, different methods.

A. Yeah, the methods are going to be different.

Q. Yeah, if the methods have to be different when studying herbicides vs insecticides, we have a bit of an institutional problem, in that my project would have to be funded through EPA, EPA is pushing a particular method, the rapid bio-assessment protocol, so if we use this method, the project stands a better chance of being funded. I would like to think I can use the RBP, but we have inherent limitations with these widely pushed methods, and if people have funding behind that, then that needs to be fed back to EPA.

basic effects, perhaps you are not really elucidating things thoroughly, but perhaps you have some indicators that are affecting some species.

Q. As far as effects are concerned, my biggest concern is that we are trying to look at a picture by only looking at pixels, in the picture. Some of these methods that we are trying to use, well, did you ever look at a space shot where just some of the pixels are shown? And all you see are "0"s and "1"s. Sometimes I think that all we are looking at is "0"s and "1"s. We are not looking at the picture very well. If we were looking at effects in the ecosystem, though, we could look at the picture. Maybe being so method-driven is not so good, and maybe we should have some other methods of looking at data. And also we have to understand the regulatory impetus. I have students ask me, well, Wayne, you are always preaching all this stuff, but what is really done? Acetylcholine-esterase or total chlorophyll, or something like that. Maybe it's that we can't handle all the data, maybe that's it, which I don't believe. If you can compute Mach 5 airflow over an airframe, you can try to handle some of the data that we have. Maybe we should re-orient our thinking a little bit, and I'll throw this out, and ask you to do that.

Q. I think we should be more prudent in how we spend our dollars as those dollars are drying up because of other budgetary needs. This means that the type of sampling that's gone on over the past decade where you are collecting only 3 eggs and trying to make some sort of policy judgement from that needs to be curtailed and better planning over how we assess things in the field - not only looking at the little 0's and 1's but trying to get a picture of what is happening out there instead of picking these little things apart and then trying to put the picture together. Especially when you don't have all the puzzle pieces. Especially when we are going to get short on dollars. Things are going to get tight out there.

A. We are going to have to get smart.

Q. It is tough to get dollars now, and we need to get every answer we can with the dollars we have.

Q. And now that we are using pesticides that are not persistent, that poses another - you no longer go out and measure residues. You got out and measure effects now rather than know what the chemicals were to begin with.

A. You mean the chemicals don't have the good grace to stick around for 10 years?

Q. I think that is something that is going to drive our monitoring future.

Q. Speaking of being smart, I just came back from a conference last week, it was a Forest Service Conference. Basically dealing with Biodiversity, and I think the two take-home lessons from that conference might be relevant here. One is that most of these issues are going to have to be found from a bottoms' up basis, because the actual solution depends on the individual situation You can't have a top down decision from Washington saying that all ecosystems have to be treated in a particular way. And the other thing basically is to get the involvement and to predict what the public is going to do in terms of public suits. Everybody in this room has been spared, or sort of spared the pressures that the forest service has been through in terms of the spotted owl, but it's going to happen to managers in this room. There are ways that you can predict that; there are also ways that you can start to work with pivotal groups and pivotal people who will work to bridge the gap in those ethical discussions, and I think that element is very important in a discussion like this.

Q. (Anne) I heard a couple of similarities in the needs expressed in the monitoring talks this morning. One of them was the need to define reference sites so that you know what is clean, what is pristine, what am I comparing my disturbed site to. The other need that I heard is the need to be able to say, what is the variability of my biomonitoring tool, and was that variability less than natural variability so that I can detect differences when they occur. Thirdly, there are a lot of biomonitoring tools being developed in the field, and I am as guilty of this as Wayne is, and how can you take these tools and apply them to a field situation, what is the lab to field comparisons and realities that you have in terms of these kinds of tools. Those are at least three basic research areas that I feel are basic to all biomonitoring methods that we have and I'd like to know if anyone has other issues along those lines that they would like to throw out on the table.

A. I'll tell Anne, and anyone else, I don't believe in reference sites anymore. I read a paper about Ohio streams, he said he had pristine Ohio streams. - - -SURE -! Pristine Ohio streams!

Q. Probably you were reading one of my papers, and I never said pristine. I'm familiar with the Ohio data, they had reference sites, and the reference sites weren't ever called pristine.

I never said pristine. I'm familiar with the Ohio data, they had reference sites, and the reference sites weren't ever called pristine.

A. Yes., there's a distinction there, a reference site doesn't have to be pristine. A reference site is just something you compare it to. I certainly don't think you will find any pre-colonial, non-impacted site in the lower 48. Well, we can argue about the field of paleo-ecology and how that would fit in to it. I tried that once. The first time I chaired the aquatic toxin symposium and we had a whole session on paleo-limnology, and that's why I doubt that there are any non-impacted streams, because you can tell when the colonial farmers came in and cut down trees by the changes in the diversity of the invertebrate population.

Q. We have an instance of reference sites with Canada geese, they were ingesting heptachlor treated seed in one area, and in another area they were using Lindane, which isn't on seed, it's not a problem, does not bio-accumulate, and may have been some (?) repellency. These two areas were only 40 miles apart, and the geese were mobile. But in that case we could use a reference area. In one area the geese were doing great, and in the other area they were dying and having much lower reproductive success. You have to seek these reference areas very carefully, but they are possible to find in the environment.

A. There is consensus then that reference areas don't have to be pristine. I agree with that. I wonder if one of the points from this work group would be that someone could sit down and develop guidelines for choosing reference areas when we are setting up biomonitoring programs, because there is a wide range of conditions that one worker might choose as a reference, and it would be good if there were some guidelines for selecting reference conditions for a particular project, so we could conduct a study and have some confidence that there would not be a lot of argument about the validity of the reference.

A. Do you think it would be a good idea to set up protected reference sites in various biomes?

Q. How would you do that in an agricultural setting?

A. Well, you could do a BDR(?).

Q. One of the things you would need in a reference is your spatial scale. That's related to what your problem or issue is, why you are monitoring. Do you care about something happening on a regional scale or a very local scale. There are arguments made now that a lot of toxins are very local, and that's not the major issue, and yet that's where most of the money goes. In choosing reference sites or conditions you need some kind of geographic framework, if are going to deal with a big area, it's the feeling of a lot of us at this lab that you need a geographic framework, ecoregions as Degraub (?) used. From which you can chose sites based on the typicalness of them, and in Ohio if you are looking for the least impaired site in northwestern Ohio you are looking for a place than hasn't been channelized in the last 20 years. You won't find a site that hasn't been channelized ever.

A. Also our idea of scale is important, it seems we haven't thought much about (the concepts of) island biogeography and how that affects species diversity, what kinds of species are going to be there. Things like those kinds of scalers are going to be important in choosing our various sites. Some sites won't be comparable not because of any toxic inputs but because of these other factors, just chance factors, and how do we pick reference sites to accommodate those factors, and do we need to? Just because a stream is not as large, or does not have as many riffles, or may not be as close to other areas where you could get a colonization problem, can we compensate and still use that reference site. If we assume that a reference site is good for just that area immediately around it, then we will run out of reference sites real quick! There is a lot of ecological theory out there that we are not applying very well. We need to start thinking about how to apply some of that old, well, 25 year old theory to accommodate some of these differences in reference sites.

Q. If we are interested in measuring changes in status and trends should we be monitoring accedence instead of ecoregions?

A. I don't understand what an ecoregion is. I know the definitions, but there is a lot of discussion about that, we could argue it around this table for the next 6 months. But accedence, or transition regions we can see, we pick them up on the satellites, or seeing changes in the edge effects all the time. Maybe that is where our biomonitorng program should be concentrating, on accedence of large ecosystems or landscape areas, instead of the particular characteristics of the ecoregions. Maybe they are two different questions, maybe we should be looking at the short-term changes in the accedence rather than long term on the ecoregions themselves.

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A. Yes., there's a distinction there, a reference site doesn't have to be pristine. A reference site is just something you compare it to. I certainly don't think you will find any pre-colonial, non-impacted site in the lower 48. Well, we can argue about the field of paleo-ecology and how that would fit in to it. I tried that once. The first time I chaired the aquatic toxin symposium and we had a whole session on paleo-limnology, and that's why I doubt that there are any non-impacted streams, because you can tell when the colonial farmers came in and cut down trees by the changes in the diversity of the invertebrate population.

Q. We have an instance of reference sites with Canada geese, they were ingesting heptachlor treated seed in one area, and in another area they were using Lindane, which isn't on seed, it's not a problem, does not bio-accumulate, and may have been some (?) repellency. These two areas were only 40 miles apart, and the geese were mobile. But in that case we could use a reference area. In one area the geese were doing great, and in the other area they were dying and having much lower reproductive success. You have to seek these reference areas very carefully, but they are possible to find in the environment.

A. There is consensus then that reference areas don't have to be pristine. I agree with that. I wonder if one of the points from this work group would be that someone could sit down and develop guidelines for choosing reference areas when we are setting up biomonitoring programs, because there is a wide range of conditions that one worker might choose as a reference, and it would be good if there were some guidelines for selecting reference conditions for a particular project, so we could conduct a study and have some confidence that there would not be a lot of argument about the validity of the reference.

A. Do you think it would be a good idea to set up protected reference sites in various biomes?

Q. How would you do that in an agricultural setting?

A. Well, you could do a BDR(?).

Q. One of the things you would need in a reference is your spatial scale. That's related to what your problem or issue is, why you are monitoring. Do you care about something happening on a regional scale or a very local scale. There are arguments made now that a lot of toxins are very local, and that's not the major issue, and yet that's where most of the money goes. In choosing reference sites or conditions you need some kind of geographic framework, if are going to deal with a big area, it's the feeling of a lot of us at this lab that you need a geographic framework, ecoregions as Degraub (?) used. From which you can chose sites based on the typicalness of them, and in Ohio if you are looking for the least impaired site in northwestern Ohio you are looking for a place than hasn't been channelized in the last 20 years. You won't find a site that hasn't been channelized ever.

A. Also our idea of scale is important, it seems we haven't thought much about (the concepts of) island biogeography and how that affects species diversity, what kinds of species are going to be there. Things like those kinds of scalers are going to be important in choosing our various sites. Some sites won't be comparable not because of any toxic inputs but because of these other factors, just chance factors, and how do we pick reference sites to accommodate those factors, and do we need to? Just because a stream is not as large, or does not have as many riffles, or may not be as close to other areas where you could get a colonization problem, can we compensate and still use that reference site. If we assume that a reference site is good for just that area immediately around it, then we will run out of reference sites real quick! There is a lot of ecological theory out there that we are not applying very well. We need to start thinking about how to apply some of that old, well, 25 year old theory to accommodate some of these differences in reference sites.

Q. If we are interested in measuring changes in status and trends should we be monitoring accedence instead of ecoregions?

A. I don't understand what an ecoregion is. I know the definitions, but there is a lot of discussion about that, we could argue it around this table for the next 6 months. But accedence, or transition regions we can see, we pick them up on the satellites, or seeing changes in the edge effects all the time. Maybe that is where our biomonitorng program should be concentrating, on accedence of large ecosystems or landscape areas, instead of the particular characteristics of the ecoregions. Maybe they are two different questions, maybe we should be looking at the short-term changes in the accedence rather than long term on the ecoregions themselves.

A. Exactly, and concentrating our efforts in the accedence.

Q. As I see it, the shrinking of ecosystems is a (great) concern. In the lower Mississippi Valley, I've read recently that the EPA has had to respond to litigation about whether wetlands that are proposed for development would be conserved or not, by considering, not just that particular development but the history of the whole region.

Q. A changing ecotone may bear no relationship at all to environmental pollutants, but they do affect how these pollutants are distributed or applied.

A. Oh, I think that's important, just because you see an effect, don't assume the cause. Oh, there's PCB in the fish, this must be doing it.

Q. I'm looking at biomonitoring not as an end in itself but as a tool that's going to be used to answer a question. I think you have to formulate the question that's going to be answered. If it's the impact of logging on a watershed, or is this pesticide accumulating, biomonitoring is a tool used to answer the question.

Q. Seems like everybody at this table has a little bit different view of what we should be talking about.

A. Right, I used to fool with chemical warfare precursors. It's a lot different perspective than I have now as an academic. Which I have to teach these things. (laughter)

Q. We have a place for you!

A. We have a problem in that we don't know what the big impacts will be 10 years from now. We want to be ready for it, is it here, there?

Q. That could be your question.

A. But that's not focussed.

Q. The question is focussed in trying to identify unknown impacts.

A. But I think the problem is that we have this big data funnel, have all this data we gathered, but that's not what we are interested in. We have to have a description, healthy or unhealthy, polluted or unpolluted, good or bad in the ultimate analysis!, and at the same time, the studies are so big and so expensive, that we can't do them. So in the future we want to know just what it is that we have to look at, so that we can take this small amount of the data and blow it up into the big picture, "this means health and this means sickness". I view it as a very general problem, astronomers are getting all this data, and there aren't enough astronomers in the world to interpret it all. We need some kind of codification or intuition about the data so that an ecological scientist can go out and say - he can't say it on the record or in court or anything, but he can say to himself, "this is a healthy system", even in Ohio.

Q. I think a codification or mechanization, a better way of looking at piles of data, rather than, - the mean of this pile is different than the mean of this pile - is not a good description of what health and sickness are. We need a stronger focus in terms of qualitative, not just qualitative because it has to be in terms of numbers, but a number that says "health", or is meaningful. I'll be talking about this tomorrow. It's a huge problem, and subject to all sorts of political contentions. I think that the direction that we have to go in is to reduce from many numbers to a few. Diversity indices, I think, go in this direction, but they go too far. I mean, do you want diversity or do you want non-diversity? Well, that's not what we want. I think most of you have seen cases where the diversity basically just stays flat even though the system goes completely anaerobic or whatever.

We need, maybe a handful of numbers or a handful of words, instead of thousands, and that handful will tell us what to do in the future. We need that kind of description, that over-arching vocabulary: that's the kind of vocabulary we are looking for in monitoring to reduce the data to something we can handle, and then use that handle to guide your studies in the future.

Q. Sounds to me you are saying that acquisition of data is not science. In that what we have been doing (unintelligible)

A. Even before you get a good theory you need a description of what you are talking about.

Q. Well, that kind of goal is what led EPA to develop the rapid bioassessment protocol.

A. I'm not sure taking less is taking better, though, not speaking for or against that particular protocol.(?)

Q. I'm not sure about how to take the decision about - who is going to make the decision about what information to take, or how those people who regulate will, as to which is the relevant

Q. I'm not sure about how to take the decision about - who is going to make the decision about what information to take, or how those people who regulate will, as to which is the relevant information because all of the information is so different. It becomes a person's opinion as to which information is important. What you are looking at is similar to when a physician has a patient and is trying to diagnose, and he can order a blood sample, and there are millions of things he could be looking for, and that many tests, and he doesn't do all of them. He has a first queue.

Q. Well, there's a lesson to be learned from that, and furthermore, the clinicians learned long ago to standardize their terminology

(Turn tape over)

Q. I think there's a role for a wide range of monitoring activities. Some are going to be suitable for research and some suitable for regulatory agencies, and a lot of what ends up in the regulatory agencies started out years ahead of time as someone's research proposal. But you can't answer all questions with one approach to biological monitoring. A lot of that monitoring is in place right now, but it doesn't get used once the compound is registered. Everything there is set once the product goes on the market.

Q. It's not assessed in the environment.

Q. It's set. broad-scale field assessments. It's preempted, there is no regulated follow through. The assessments are done, whether it's ? and cholinesterase, whether it's herbicide and drift on ? local plants, the direction is to the front end. In England they are very proud of their post-registration evaluation. They take in the data post-registration - mortality - any problems that come up, there is a database set up by the government which takes it in. There is no legislative means to do that here.

Q. That's a very important point, the (matter) of follow up after registration. We don't even know where pesticides are being used, or how much.

Q. An extremely important point is that all the pre-registration monitoring that is done is done on a single compound on an isolated site. Nothing is done where you are looking at 50 square miles of compound or on a mosaic of agriculture where different compounds are used on each crop. I think that a lot of the background and a lot of the basics to the monitoring process are in place now, but they are not being applied post-registration. That is a strong direction that needs to be followed.

Q. Which is why we are here.

A. See, Mike, I would disagree that the biomonitoring is in place, especially when you compare it to Europe. Western Europe. Up in the North Cascades - what biomonitoring!!? It always seems that we are doing crisis management. Why was there an acid rain program? We didn't believe in acid again until January 21? (political character to next comment!) This is stuff that a graduate student came in and talked about in 1975! "This is a national problem, maybe we should think about doing something about this.!" But, what got all the monitoring programs going is when someone said there might be a problem. Biomonitoring is not in there until someone wants to prove that [a substance is] safe or dangerous.

Q. That's what happened in Idaho - someone called us up in SE Idaho, said "We've got a field full of dead sage grouse."

Q. That's the other point, a lot of times you don't know what you've got out there. California is one of the few states where you can get lists of what's been applied.

A. In the great environmental State of Washington, we wanted to know what kinds of pesticides had been applied. The Department of Wildlife came back and said, "Forget it." They couldn't get lists, even on an anecdotal basis.

Q. I think this a point we are missing. I know this is biomonitoring, but this also has to do with the farmers. I think we need to work cooperatively with them. We know what the value of wildlife is, and we know these things are affecting wildlife and fish. We need to educate these farmers while we are monitoring.

Q. I think that the passage of the farm bill with the large leasing program indicates the public concern in this area. The farmers farm the policy, they don't farm what's on the land. I think that the other group on risk assessment is probably talking abut it. There are two sides of the coin, there is risk and thee is hazard. So far, all that we have been talking is about is hazards or effects. So, are there systems in place or things that people are working on to look at exposure, - and not just doing analytical chemistry. Jerry Bromenshenk's bee populations, for example, can they be used to look at exposure? What is bio-available.

Q. What Jerry's doing with bees can be done with other forms of free-ranging wildlife, but it's extremely expensive to do, for example with songbirds. Jerry can get his hands on five billion bees in ten minutes. To do that same kind of thing with vertebrates would be prohibitively costly.

Q. I have a ? next door to me, now these farmers know what's going on their land, there are certain subtle effects that they don't know about, but I think in a lot cases they can educate us.

Q. None of them are required to report or identify effects. It would seem like all too often it's easier to hit the applicator or the companies, but the end user may have a responsibility, too, in monitoring and sending that information off to the regulators so that they can make better policy. I think of the wealth of data that's available in the farm belt, on herbicide and pesticide use that the corporate farmers have in the breadbasket of America, I'll bet you they would fill this room up with reams of data that we have never even considered, nor would we know how to use. Probably if put together it would give a pretty good picture of what has occurred over the years, and is available through recordkeeping that they may have on their own personal property.

Q. All too often I think we focus too much on the applicator instead of the end user.

A. I think, in answer to your question, that the effects and concentration both need to be looked at. OP's tend to have certain effects. Also you can look at enzyme induction, community change, things like that. Referring to the biomonitoring question, you know, Weather balloons are sent up twice a day from thousands of stations across the country, and they gather all kinds of data. We don't have anything like that for biological information. I'll bet we could answer questions about effects and concentrations and so forth if we looked at things in similar fashion, and it was all timed together in some sort of routine fashion - and I'm not talking EMAP here, either.

Q. I think it might be useful to focus in on what we mean by effects. I thought I heard Bill Cooper say that he's not really aware of any effects on populations, and that's not something I agree with, because I think that in some of our raptors we saw some effects. So, are residues effects, and is that really significant? and Larry had 43 dead sage grouse down there. Is that significant? I mean there's still sage grouse down there where they are spraying. So I think that is really an important point that he made, that is, what is the effect on the ecosystem and on the species, versus residues, and some mortality that may or may not be significant. You know, we are throwing this word 'effects' around here, and I'm not sure what level we are talking about. You can measure the effect on a species so easily, in terms of population change, compared to defining an effect on an ecosystem. You can say, well, there's a reduction in this population and a rise in that one, and so I can see a change, but is it an absolutely irreversible change?

A. We had that question about enzyme induction. Is that really an effect? does it really care or not? That's a good question. I think the answer is, it depends on what you are trying to protect. If you are trying to protect some bird, an endangered species, then that's an important effect. If you are trying to support an agro-ecosystem, it's a broader-term effect. Your effects are scaled. Some of your smaller effects like enzyme induction may give you information on concentration and so forth, but they may enable you to make other kinds of predictions. We tend to think of long-term as a year. - - -The things that we are looking at now, well, you were kids when the initial inputs were put in. And the things that we should be looking at now, we won't see for another 10 or 15 years, so that's why Anne's point about being sure we can see concentrations and so forth, that could be important because those are things, that, on a larger scale could have an effect down the road.

Q. I think that our discussion just keeps returning to the persistent compounds that - and in terms of herbicides, certainly in surface water systems, transient systems, we are talking about transient, episodic events in terms of the exposure. To put research money into trying to monitor these chemicals when they may only be in the system for 12 hours to a few days, is difficult. I'll give you one definition of effects that I think influences a lot of people. We deal with aquatic systems, and we say an effect is any measurable adverse impact on aquatic life.

Q. That's begging the question, though, what about birds (or vertebrates)

Q. I can demonstrate that there's no adverse effect on a heated lake at the Savannah River plant, at about 45° Celsius. If you really want to stretch the term. That word adverse is a notoriously difficult problem to approach, and is only as good as the people who assign it.

Q. If you can identify effects, and the public is aware of those effects, then the question of the relative importance of those effects will be addressed by the public.

Q. I didn't say significant adverse effects, I just said adverse effects. If you caused significant drift in a population of invertebrates as a result of applying a chemical, then I think that would qualify as an effect.

Q. I want to go back to the previous question. I work in the Department of Fisheries, and down in Willapa Bay they spray Sevin to control ghost shrimp, because their burrowing activity causes oysters to sink into the mud. Sevin, or carbaryl is a short-lived chemical in the environment. However, it has adverse effects on organisms other than the target organism. How do you measure the effects on other organisms, such as the organisms that the juvenile salmon feed on?

A. You are talking not about the direct effects, but abut other perturbations, and that may only be determined by the it's historical lesson-makers. You are killing all the juveniles, that alters the age structure, you are killing all the adults, something else - you will see an effect that is going to be passed on for several years, depending on the cycle of the organism, not just due to the persistence of the chemical.

[Confused, but animated discussion about what biomonitoring means: not tissue residues, but long-term community monitoring, says one.]

Q. Biomonitoring means too many different things.

Q. We have to define the problem before we start monitoring. This gives you a general idea of what kinds of things you have to collect before you start sampling.

The other problem is the information explosion. Wayne Sam's (?) studies are about as simple (interject: 16 species), yeah, 16 species, about as simple as a multi community (?) study can get, and yet the information from those 16 species is too much for one person to handle. Making all that information into something that is understandable.

Communicating between groups is another issue. Lots of people are biomonitoring now. We have seen a lot of examples, indicating that nationwide, there are a lot of reference sites but do you know about them unless you have been to this conference this morning? How you get information on reference sites, I've just been through this with a river basin, I was just looking at the list of people that I have to call just to find out if there is any information that has been collected so far. It goes on for a page!

There are some overlying problems, that pertain to all biomonitoring, but if we go beyond them, we are going to have to get a little more specific about whether we are talking about herbicides or insecticides, whether we are talking about predictive or retroactive. I don't think DDT is a dead issue, it's still there, if you are asking the question, whether it's still out there. We already found out that it's no longer all DDT, the undegraded DDT is 40% of what's out there. So it's not a dead issue if you want to know what's coming into the system. But if you are trying to predict, for new pesticides, it's hopeless.

A. A friend of mine, Jess Patton, takes biological receptors, puts them on a piezo-electric crystal, or something like that, so that a toxin can actually react with this biological entity and he can get a reading. Is that biomonitoring, or is that analytical chemistry? If you are interested in things like organophosphates, you look at cholinesterase. It binds right there. Or what he's done is look at T-2 toxin. He's got receptors for that. T-2 binds to it, and it changes the frequency of the crystal, So, that kind of bio-monitoring takes most of the junk away. I think that would be a very useful technique for measuring for one or two chemicals.

Q. You made the statement in your talk today that everyone in this room, according to their cholinesterase, may not be functioning, so what.

A. The "so what" question is important, too.

Q. That gets back to the question of whether you are trying to monitor for exposure or for effect. I think that cholinesterase is an example of people trying to use what is primarily an exposure marker to define effect.

A. and: "Ask the right question"!

Q. In terms of asking the right question, it seems to me that we never did talk about having a goal here, in terms of biological monitoring. I think we should establish some goals and then get into technical discussion of how to reach those goals.

Q. I'll throw one out now, and that's monitoring change over time, I think that's why it's important to perfect the technique now that'll be consistent. In the chemical water quality data, for example, there are very few cases where we can go back 30 or 40 years and have been monitoring the changes that have occurred over time. Where we have the rare data set they are extremely useful. As soon as we can achieve some consistency in data collection - biological data collection, that will give us an extremely powerful tool to use in the future. We have to think about the immediate short term project,for goal setting, but we should also think about the basic representative data that can be used in logical ways 20 years from now. People may use that data in ways that we have never even thought of.

A. I think that's a pretty good outline. There are several questions coming out - there is the question of basic techniques for the long term, there is information processing. Communication is another important topic. Developing standard methods takes time and communication. But at times it seems that techniques drive the monitoring process more than the question you are asking. It's good that we have the risk assessment workshop, too. I have been to some risk assessment conferences, where they ask us to get dose-response curves for all these different age groups in the population. Now that's crazy!

Q. Another goal that I can suggest is the "so what" question. From a management position, to turn an "effect" into a damage assessment to an ecosystem. The dollar drives everything, and in the case of superfund sites and so on, [we have to] place a dollar value on natural resource damage, to assess the responsible party so they fix it. Hey, it's a nightmare!

A. Another committee that I'm on, we ask, "how clean is clean".

Q. A lot of people in Europe think that we are way too clean, orders of magnitude too stringent. Also in other places around the world, It's a question of social values.

Q. One way to get at that is to sample along a gradient from clean side to polluted side, so that you have more than two samples. I think the "so what" question is obviously the most important question. That sets up the question (?), and your techniques.

Q. I'd like to get back to that subject of using farmers as monitors. They have access to a lot of information, but there isn't a system that coordinates that information. There's no framework that farmers report to extension agents, . . .

[an extensive discussion of the veracity of farmers and the scruples of produce buyers is deleted. The general point was that farmers will cooperate with research workers if they do not think their own livelihood is being threatened.]

Q. From a toxicological sense, we look at cause and effect out there, but the bottom line is being used because the market dictates that the potato that comes into the store has to be perfect. It has to be a certain size, no knobs on it, the apple has to be a certain size and color. We have to change the attitude of people to minimize the amount of chemicals being distributed out to the environment. This would take care of a lot of our problems. For example, where I'm working right now, they are using over 34 chemicals in a small area - Klamath Falls. And, that's a lot of stuff! And they are putting stuff together, we don't even know how it works!. They are putting fungicides with insecticides, they are putting other chemicals, two different insecticides together. We don't know how that enhances, etc.

A. I'd like to come back to that

Q. I guess the bottom line is we have to change not only our way of doing things, but change the attitude of the country. We are a monocultural society right now, we grow one kind of tree, one kind of crop.

Q. There is a dramatic change underway in farming. In 1980 there was an estimated 200,000 farms registered in organic farming, and now I think the figure is 500,000, so that is a positive end that is occurring, and a lot more people are seeking organically grown produce in the store.

A. And some farmers are growing part of their crop organically and some not. They say, if people will buy it, I'll make it! But we've gotten a long way from bio-monitoring.

Thirty seven different compounds being used in a particular county. Can you imagine trying to quantify all the effects, concentrations, and so forth? And that's not a-typical.

I go back to the question about how you take things from the lab to the field. In this case, you don't. I think the lab has a function, in predictive estimates and evaluations between simple combinations, but as far as when you get out in the real world, multiple applications, different soil types, different environments and so on, you are not going to do it.

Q. I think sometimes there are red flags out there that help drive our system. Declining populations of one species or another, piles of dead die-offs, you guys in the lab may come up with something that says, "hey, this doesn't look right". in which case you take that work to the field to experimentally manipulate an area to get a better handle on what goes on, but I think it's a bits and pieces approach, that you have to build, as opposed to understanding the whole system at once.

A. Is anyone getting tired?

(end of day)

Summary

Wayne Landis

Well, we had an interesting discussion, and that pretty much summarizes it, right. I'll go through some of the things we talked about, and if I got it wrong, I'll let you all correct me.

Biomonitoring - one of the things that was brought up was, maybe we should drop this organochlorine paradigm. I think that is pretty important, because we keep talking about things lasting in the environment for 10 or 15 years, and the new types of chemicals we have probably aren't going to be around, at least in that chemical structure, for 10 or 15 years, because they are designed to degrade. It's not that we should forget about DDT and DDE and all our classics that have funded our research for so long, but we are going to have to get smarter in some ways, and look at effects that may be secondary and tertiary. The chemical has come in and wiped out the trophic level or has altered the age structure of the population in some way - and all we see is the reverberations beyond that. Perhaps we need to get more sophisticated in that way. That I think was one of the major points.

Then it kind of fell apart, I was able to hear three or four conversations going on at one time as people talked to their neighbors. And it was fairly interesting. One interesting thing was that, with 30 or 40 people in the room, we had about 15 to 20 different definitions of biomonitoring. But that is OK, because biomonitoring is any time you use a biological organism in what you are doing. So biomonitoring isn't a particular technique, but is lots of different ways of asking different questions. The most important thing is to define carefully the question that you are trying to answer - which makes it a lot like traditional science, where you have a question you are trying to answer, and pick an appropriate tool.

In biomonitoring, sometimes the tool tends to run the question, instead of like science, where you ask a question and then try to find the right tool to answer it. You have a technology, and you have look for questions to ask. The feeling was, we should start with the question.

Another question was information, we sometimes have reams and reams of information,but we don't deal with it very well. I know from just a multi-species toxicity test you can get reams of information, but what does it all mean?

Sometimes, we want to feel that we are doing the hardest thing there is to do in science. We work with the most complicated system, it must be the hardest thing there is to understand, we may never understand it! It sounds to me almost like vitalism from the last century, where life is something unique, and we can't hope to understand it, it's like magic.

As scientists, we don't believe in magic. There are ways of handing large amounts of data, and we are going to hear about some of those this morning. If astronomers can do it, by golly an ecologist can do it. We have to get a little smarter and more sophisticated in how we deal with information.

So that's something else that came out, we get lots of information, how do we deal with it, how do we reduce it to something that really describes the picture that we are trying to draw.

Following that it came out that there is a severe lack of communication in biomonitoring, that there is lots going on, but you can't find it, or them. There are lots of biomonitoring programs, but the data gets put away in NTIS or somewhere else, because no one is going to publish all the data in a journal. So sometimes it's in the grey literature or in someone's file somewhere. So there is a feeling sometimes that there is a strong lack of communication, that there is information that may be applicable to someone else's project, but you can't get access to it. You can't find out what's been done.

Another thing is that our QA and QC for field studies isn't what it should be, like, does anyone else ever go back and sample the same area? do we have any sites that we can really use as control sites, where we know how many animals there are? Or control plots, where you put animals out there and count them, to see how good your mark-recapture is. Those things are often not done, you often don't have an idea of your precision or accuracy in a field study. And you can see that in a stream survey. You don't know how many organisms are out there, but you can replicate it by having one guy go down there, and then another guy go down there. Someone sarcastically said, well, then your error bar is going to be like this!. But at least you have error bars, and have an idea what kind of information you are drawing your conclusions from. And I'd just as soon see error bars that wide. Sometimes the errors in populations tell you a lot about the contagion of the population, if you sample through the year they give you some idea of the boundaries. As Cooper was saying, sometimes you get oscillations between minimums and maximums, bounded oscillations. In aquatic systems, I'm used to that. Spring and fall turnovers, stratifications, chemistry changes, sometimes things change from meter to meter. It may be a good idea to have some idea of what that fluctuation is for a couple of reasons. One is, so we don't draw conclusions that aren't justified. Sometimes we draw unjustified conclusions and a lot of money is spent fixing something that may not have been broke. So replicability is important,

And, writing down the QA/QC is important, too.

Another important question is, So What! So you find a 10% decrease in population, or you find 30% acetylcholinesterase in blood plasma of an organism is inhibited, or that they switched on a certain set of stress proteins. So what? It's not that we don't think it is important, but how do you quantify it, or extrapolate from that to put some kind of economic or social value on it?

We have seen that in the BEEPOP talk yesterday, where they put population models, fitting those into what kinds of effects we are seeing. I'm sure we can do that on a more molecular level, and the "So what" question is becoming more and more important. So what, you find PCB's in fish tissue. is that really important or not? I heard one fellow, I'm not sure if he was being sarcastic or what, but he said, "So what! I have these regulations I have to meet. That's what's important!" I can understand that, but overall, the so what questions is, does this really have a significant biological effect?

We went through lots of research questions. I made a sarcastic comment about a report I'd read, about a reference site in Ohio about a reference site, supposedly the most pristine site in Ohio. Some guys from Ohio said, "We didn't say pristine!"
How do you define a reference site? That's fairly important. In science, you should use a control. NSF has a program where you have reference sites in different parts of the country, but one reference site is good only for the area immediately around it. The point was made that there can be lots of different kinds of reference sites. There is probably not a "standard" reference site, a reference site may be good for only one kind of measurement. For one particular pesticide, you might use a reference site that doesn't have that pesticide, but that doesn't mean it's un-impacted. If you can find PCB's in Antarctica, it's unlikely that you will find a reference site in North America that hasn't been exposed to some kind of toxicant. But you can use it as a control for the pesticide you are studying.

Variability in ecosystems. We talked a bit about that in terms of replicate sampling and so forth. Ecosystems are variable - they are designed to take into account the variability in the environment. How to incorporate that variability into our "so what" question, to know whether the variability seen in our physiological, biochemical or behavioral indicators say something is wrong with the ecosystem.

Extinctions: even though Audubon or Greenpeace won't admit it, extinction occurs, even without man. I'm not saying we don't accelerate the rate, but it occurs.

[There is] variability in population numbers, we know that, but how do we incorporate it into our models so as to answer the "so what" questions? How much of the variability is anthropogenic? Does the frequency of variation indicate anthropogenic influence?

Lab to field. What are the things we have to take into account when we go from lab to field? I said, sometimes we don't do very well at that. Anne looked at me and said, Wayne, you do as well as anyone at that. You work in the lab, you don't have any idea what the relationship to the field is. I said, yeah, give me money! There are a lot of things like physiology and behavior that we study in the laboratory so that we can start to get a handle on it. Now, how do you extrapolate that to the field. Unless you are in an experimental lakes area, you don't just go out and dose a lake with a pesticide. So how do you get from the laboratory to the field? The laboratory is not the reality that we are trying to protect.

Concentration effects. In the laboratory, we write up protocols to see that we get a good dose-response relationship. Increase the dose, you get a larger response. But is that important in biomonitoring.? Is it important in sampling in the field, that you be able to tie in a concentration to a certain amplitude in response? That's important in the lab. If we get a nice dose-response curve we say, "Oh, we can publish this now." If we don't, we may have to do some more concentrations before we have something worth reporting. But in the field you don't have that luxury (implication - your concentrations in the field may not give you a range of responses). And how do we deal with secondary and tertiary effects, where the chemical is no longer there. What you are seeing is the change in structure from the chemical that was there, perhaps in the last growing season. The nice thing about the organochlorines was that if you see an effect you can still find them, and even if you don't see an effect, you can still find them! What are you going to do with a compound that is more readily degradable, and the effects you see may not be so straightforward. How do you tie in a dose-response? I think that's going to be real interesting, especially when you take it to court.

That's our discussion, boiled down to a synopsis, and I guess what I noticed is that it was a little chaotic.

One of the things that bothers me is that we don't see anyone from DuPont, or from Ciba-Geigy. They might be able to tell us a little bit about what's coming down the line. I think that they have some of the same fundamental concerns that we do, perhaps from a slightly different point of view, because the last thing that they want is to put something out there and then lose $20 million or so, because it turned out to be bad. Their points of view would be interesting.

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Any **questions or comments**? Does anyone see how risk assessment and biomonitoring actually fit in? I think that is semi-important.

Q. I think we do bio-monitoring as a tool to have something (information) to put into risk assessment. An interest of mine is quality assurance. I think the physicists and chemists are deeply into quality assurance, but you ask a bird person how they do quality assurance, and they will say, "well, we use the Scientific Method!" And that's the end of it.

[In the following transcript, extensive discussion of the process of registration of pesticides, of whether proprietary information on formulations should be available to EPA and/or the public, and of, e. g., whether field testing should be required prior to registration is omitted or condensed.]

Q. More use should be made of pre-registration data in deciding which products may be an environmental problem. If we note that a product has been shown in pre-registration studies to have an LC_{50} of 1 ppm, we would suspect that it may be causing damage to wildlife. This kind of study would lead to predictions about which compounds to monitor for. Also, I think that EPA sometimes allows compounds to go out even though there is information pre-registration that suggests they nay cause environmental damage.

Q. (Firestone) pre-registration field studies are being done now, but there is no legislative process requiring that post-registration database be established and filled in.

Q. (Anne) The legislative authority is present. It is not being enforced. There is another problem, that much of the information generated pre-registration and submitted by the manufacturer, is confidential for proprietary reasons. Presently, Risk Assessment occurs pre-registration, and often post-registration by agencies interested in environmental hazards posed by pesticides, and field data from post-registration studies can be useful as evidence in the case where a review of registration is conducted on grounds of possible environmental risk.

A. The thing that bothers me about that is in the field studies, it can be claimed that the effect seen was due to another chemical or some other environmental factor, particularly if the chemical is one of those non-persistent ones that we use today.

Q. Is there independent testing done to verify manufacturers' submission?

A. (Anne) Only if the EPA reviewers find evidence that there is some problem with the original submissions.

(comments: industrial labs under economic pressures to simplify testing as much as possible.)

Q. I take exception to the comment that methods are available. Methods may exist, but their availability is extremely limited. We had to drop some of our testing because methods were not available to us. Some of the methods that we used were actually developed by another EPA section, the industrial waste section, who was interested in finding pesticide residues in sludge samples. I believe the USDA developed their own protocols for their analysis. In my opinion the most limiting bottleneck is not in developing field methods, but in finding those analytical methods.

A. Anne brought up the point that we use biomonitoring to mean two different things. We use biomonitoring to measure concentrations, and we also use it to determine if there is an effect. You hope that those two are compatible.

Q. We are talking about testing before and after registration. In a plant testing workshop here in Corvallis two weeks ago on effects on non-target species. As a newcomer to the field, it appears to me that field testing is not done in a regime or by a means that would give any information on how those herbicides affect plants in a community. They are tested in row crops, but they are not tested in competitive situations such as would exist in nature.

A. You mean competitive interactions don't exist in the laboratory?

Q. Row-competitive. So, I don't think we have the information necessary to identify the effects that pesticide would have in the field if we haven't tested it in a field situation before registration.

A. Someone Robin, I think, got on my case about the cost of these protocols that we have to follow.

Q. (Robin) Well, the other part of that comment was, that if you expect people to use standardized methods, then you should make those standardized methods available at a very low cost. Subsidize your journal some other way!

A. Come to the ASTM meeting in Atlantic City:

Q. When monitoring for effects, rather than exposure, for example when we sampled in the Yakima valley, we found lots of chemicals, DDT, DDE, and so forth. I am asking, what are the effects that we found in the Yakima valley that are due to those chemicals? and I submit we can't answer that question. I think you are proposing a question an order of magnitude more difficult, [saying that] I can take a particular chemical, go out and apply it in the Yakima Valley, and tell you what the effects are going to be. Am I missing something?

A. probably we are not being real!

Q. A very important question is mechanism of action of a compound. We need to know how a chemical works, at least initially, within an organism. Knowledge of this sort is essential in effects bio-monitoring, and it can drive biomonitoring (design of studies?).

A. Initial mechanisms, such as acute toxicity, may not be as important as some secondary effects. I just read a paper indicating that OP's inhibit DNA repair. Now, we always assume that the effect of OP's is acetylcholinesterase inhibition, but

End of Tape

molecule, now that's something else that may or may not have a significant impact. but I'm not saying that the acute mechanism is the only one that we need to know. The other thing that concerns me is the mixture question. We deal with effluents a lot. Aquatic tox started getting more and more into biomonitoring because the organism was answering the mixture question itself saying, saying, "I'm real sick, I'm going to die". Even though you can't measure anything in there that's causing this, you are seeing toxicity. You see an effect, and it could be due to a number of compounds.

Q. Measuring exposure and concentrations has the advantage of giving you hard numbers, so you can calculate bio-availability and things like that. That tells you who is at risk, basically, but doesn't tell you much about the effects. I notice a tendency in the discussions about effects to say, well, do effects and you won't have to do all that pricey chemistry. Well, I'm here to tell you that when you get into court with a bee-kill case, where you've got an effect and you've got a chemical, at levels five times the toxic limit for bees, and the bees all died, there are folks who will still get up there and tell you, well, we don't know whether it was actually this chemical. So I still don't know how we get from cause to effect.

Q. Well, we talked yesterday about taking a tiered approach, in which effects monitoring might be a first step. That also fits with the original idea of this workshop, which was to talk about a second kind of monitoring called damage assessment. We've made decisions, up to now, using a lot of data in terms of cost, but not a lot of data based on information of the variations on natural systems. So lets go out and lets see if those decisions were good ones. And as we do that, with all the chemicals and formulations available, we really can't afford a chemical by chemical approach. You almost have to look at the broader effects. They may not be due to pesticides at all!, but that's what you have too look at.

Q. Just to clarify a little bit the work in the Yakima Basin, that work does not include just the tissue residue work that I talked about yesterday. That work would mean lot less by it's self without all the other monitoring that is being done. We will be looking at plant communities, invertebrate communities, fish communities, at the same time that we are doing the tissue work. We will also get information on pesticide application, population changes, water chemistry, sediment chemistry, and hopefully we will be able to put these things together into something, well, cause and effect is the way we would like to go.

A. One thing that we don't put much of our effort into is the connection between site of action and the effects in the ecosystem, and how we get from one place to the other. We know it happens,but we don't put much effort in it. We are talking about the site of action in the organism, and it's effects at the ecosystem level. Environmental toxicologists don't seem to look at that very much, We seem to be satisfied with correlational effects.

Q. In order to do this deterministic level of process it takes a very critical level of information. It takes a critical level of experimentation that most of us don't have. What we hope to get out of the Yakima Survey is evidence from a few of the levels or bits of information that say, "here is something that indicates that something is going on, here is where we should concentrate our efforts. The survey will hopefully narrow our focus to a few points where we are likely to get positive results, and thus we can afford to expend the extra effort to achieve some deterministic results. There are really two levels of research here, the correlational, or where the results are, and the deterministic, or the process.

A. Yes, which is what we can do at the molecular level.

Q. There is the complication that with some of these newer herbicides, you may not even be able to detect the herbicide on the target crop, much less on the over-sprayed plant. So the thing that caused the effect may not be around when you sample.

A. Another problem is the use of adjuncts that increase the effect. One thing that bothers me is the fact that all these things eventually get into the water, and go downhill from there, into the oceans. A watershed takes stuff up from all land uses. We are studying water samples right now with fish, using the cough response, and we find that even though the fish goes through all of the cough behavior and respiration changes, that when we do the chemistry, there is nothing there that we can detect.

Q. It seems to me that our concern about discerning cause and effect is misplaced. We are doing principally ex post facto studies right now. It seems to me that all we have to do is shift our emphasis and set up appropriate experiments, where the intent is to show cause and effect a priori, We want to do good treatment replications, cross-over experiments, and that sort of thing.

A. I think some of that is being done in the registration process, but I would like to see this sort of thing being done with several materials added together, mixture effects and so forth.

[end of session]

Lichens as Biological Markers

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ABSTRACT

Lichens have been used as biological indicators and monitors for over a hundred years. Physiological processes make lichens excellent collectors of atmospheric particles and gases. The ubiquitous occurrence of lichens, as well as their ecological position on a variety of substrates, facilitate their use in many different regions. Vegetation mapping of lichen species can show the degree and zones of influence of various chemicals. These biological markers can be less expensive to use than other types of monitoring equipment. Biological markers monitor 24 hours a day, 7 days a week, and can detect the rare or stochastic event of chemical releases. Some lichen species can be transplanted into an area to evaluate pollution. This evaluation can vary from detailed chemical analysis to merely recording weight changes.

INTRODUCTION

In 1866, Nylander was perhaps the first person to make a definite statement on the sensitivity of lichens to a city environment. He wrote about the impoverished lichen vegetation near Paris, France, stating that lichens provide a means for measuring the quality of the air. In England, many of the epiphytic lichens growing on tree branches were reported to have been killed by "smoke." The first experimental transplanting of lichens onto trees occurred in 1891. These lichens died shortly after being placed in sites where smoke was present.

There has been a general decline in lichen species and abundance in many cities. Barkman (1958) reported a 27% decline in the species of lichens within the last century in Denmark. Barkman developed air pollution sensitivity ratings for various lichen species. Epiphytic lichens are especially sensitive to pollutants. Species such as Lung lichen (*Lobaria*), Old man's beard (Bryoria and Usnea), and Shield lichen (Parmelia) have disappeared from many urban areas (Barkman 1958).

Why Use Lichens as Biomonitors?

Physiology:

Lichens are slow-growing, long-lived plants with no true roots or waxy cuticle. These plants filter out and accumulate chemicals from the atmosphere. Lichens growing on tree branches (epiphytes) receive very little buffering effect from their substrate. This makes them susceptible to atmospheric pollutants, thus providing excellent early warning systems comparable to the canary in the coal mines warning miners of dangerous gases. This sensitivity has increased because, unlike vascular plants, lichens never shed their toxin-laden leaves.

Numerous studies have shown that sulfur dioxide, fluorides, ozone, heavy metals and other gases negatively effect lichens, both in the field and under laboratory conditions (Gilbert 1965, Nash 1973, LeBlanc and Rao 1975, Rosentreter & Ahmadjian 1977, and Nash 1988). Fields and St. Clair (1984) found that sulfur dioxide interfered with normal photosynthesis and membrane permeability. Many studies have established the correlation of pollutant levels with lichen growth. Some studies have used fumigation in the lab while others have used field transplant studies. Lichens signal the effects of air pollutants and are likely to signal the effects of other perturbations.

Ecology:

In addition to their physiological susceptibility, lichens occur in many sensitive ecological locations which make them well suited as biomonitors. Lichens grow on many different substrates including rocks, soil, trees, shrubs, boards, and many other man made structures. In contrast to larger, more complex organisms such as trees, they are small, easy to move about and are suitable for testing under various laboratory conditions. Studies involving lichens can often be accomplished at much lower costs than studies on other organisms. Lichens occur in all types of habitats. For example, an area lacking trees may contain lichen species on a fence post or on a sagebrush shrub.

How To Use Lichens as Biomonitors

Evaluation methods:

A site can be evaluated by: 1) recording simple presence or absence of key lichen species, 2) estimating the percent coverage by the lichens, 3) measuring the frequency of specific species, 4) recording the number of species present (species richness), or 5) measuring transplanted lichens for weight gain or loss. Mapping the distribution of various lichen species can demonstrate the zone of influence of a particular point source of an air pollutant (Hawksworth and Rose 1976). These maps often show a large area of influence downwind from known sources of pollution. Several species of lichens can be used for this mapping, or a single common and conspicuous species can make the mapping relatively simple and rapid.

Studies may examine the species composition on a single substrate such as red oak tree bark or several substrates may be sampled. Transplanting branches or tree bark cores are valuable methods for biomonitoring due to the flexibility of moving the transplants to sites producing a gradient of conditions for analysis. Transplanting nylon strings of lichens and weighing them can be an accurate measure of environmental conditions (Denison 1973). Lichens have been transplanted to evaluate air pollution. Direct observation and measuring the increase in area or diameter using sequential photographs have been used to evaluate growth and health of lichens.

Species Composition:

The presence or absence of key indicator species has been used as a kind of "litmus paper" to map levels of sulfur dioxide. As passive collectors of gases, lichens can accumulate toxins. These chemicals can be analyzed directly or the presence of specific lichen species can indicate relative abundances of various known chemicals. Ryan (1990) has produced a "Preliminary list of pollution tolerance of lichen species" for North American species. Many other authors report on pollution sensitivity of lichens for a given site or smaller region. Wetmore (1988) and Hawksworth & Rose (1970) correlate lichen sensitivity ratings to definite concentrations of sulfur dioxide, as specified in those articles. Many laboratory studies have shown differential sensitivity to specific individual pollutants. However, direct correlation in the field is much more difficult to prove due to the cumulative effects of other chemicals and other ecological factors.

In field studies near Indianapolis, Indiana, McCune (1988) found a correlation between lichen communities and sulfur dioxide peaks, while in contrast, ozone peaks did not correlate with the lichen communities. Lichen communities and tree growth have also been studied in relation to a point source of pollution by Muir and McCune (1988). Direct effects on lichen communities caused by the application of pesticides in the forest have not been studied. It is assumed that lichens would be sensitive to such chemicals and may be indicators of drift or of increases in the general area being studied. Forest declines are common in Europe and North America. Lichens present in forests have been used as early warning indicators of forest dieback (Scott and Hutchinson 1989).

Chemical Analysis:

Lichen samples can be analyzed in the laboratory for the presence of heavy metals (Lawrey and Hale 1979). Analyzing samples of lichens taken from field sites for chlorophyll content or electrolyte leakage has been used as a more refined indicator to evaluate the health and vigor of these lichens (Belnap and Harper 1990, Fields and St. Clair 1984). One advantage of these laboratory tests is that a very small amount of material is required for analysis and that monitoring results are quantitative.

Field Monitoring Methods:

The United States Forest Service has established a draft "Lichen Monitoring Protocol" to evaluate air quality in Class I Air Sheds as mandated by the Clean Air Act of 1977 (USFS 1987). At this time it includes four major types of sampling: 1) lichen plots, on rocks, 2) lichen transects, on trees, 3) lichen collections, and 4) lichen transplants (USFS 1988). The first two methods utilize monitoring of species composition and frequency within permanent plots. The lichen collections are floristic studies to establish baseline inventory and flora richness. The last protocol, lichen transplants, can provide data on growth or decline rates and changes in species composition. Transplants may be well-suited to pesticide studies when the area of application is known.

Pesticides:

Use of lichens to monitor pesticide application or movement has yet to be documented. However, the wide use of lichens as indicators of other chemicals suggests that they may be well suited. Drift of a pesticide over a stream could be measured by placing a lichen specimen which is found to be sensitive to the specific pesticide in the air space over the stream in question and observing the lichen's health over a period of time. Transplanted lichens or naturally occurring individuals may be affected by a rare or unusual event which direct observation or spot testing by expensive equipment may miss. Many of the lichen evaluation methods discussed above are simple and relatively inexpensive to conduct. The ability to detect small amounts of pesticides is reassuring to the public. This detection can be of use for people who want to be assured that pesticides are not moving to non-target sites.

SUMMARY

Lichens have been used as a biological estimation of air pollution and have potential as indicators of pesticides in natural ecosystems. Studies indicate that the pollution sensitivity of lichens is relatively high compared to other plant groups. Similar to gaseous pollutants, pesticides are applied aerially and are likely to be absorbed by plants which are sensitive to atmospheric chemicals. Sensitivity scales for specific pesticides will have to be developed based on species richness, community associations and individual tolerances. It is also possible to evaluate pesticide effects by critical appraisal of the physiological or ecological performance of a single species (Seaward 1987).

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Bees as Biomonitors for Ecological Risk Assessments

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Honey, bumble, leafcutting, alkali and other bees are indispensible pollinators of many ecosystems. Pollination efficacy can be altered by natural factors such as weather, parasitism, predation, and disease or by anthropogenic intrusions such as pesticides, industrial pollutants, and hazardous wastes. As part of the pesticide registration process, FIFRA requires testing to evaluate toxicity and hazards to these ecologically and economically important organisms. This has resulted in the development of standardized procedures for assessing chemical hazards and in a substantial toxicology data base. In addition, bees have been utilized as exposure and effects monitors of pesticides and other toxic chemicals in ecosystems ranging from semi-arid deserts to forests, in urban and rural settings, and in agricultural lands. Spatial scales have varied from a few meters to landscapes and regions; temporal scales from hours to years. Assessment endpoints include responses at levels ranging from the organismal and suborganismal through populations and communities and employ measures of bioaccumulation and other biomarkers of exposure, as well as changes in population composition, size and function. Over the past ten years, we have developed specialized equipment and refined procedures for sampling bees and measuring these responses. To increase data comparability and to assure data quality, we generated a set of recommended assessment protocols. To better use and interpret this monitoring information, we developed an ecotoxicological model: PC BEEPOP, a honey bee population dynamics model and dose-response database. The model is particularly useful for associating exposures and effects and for delineating responses to natural versus anthropogenic stressors. The abilities and limitations of this approach will be illustrated by case studies and will be discussed in the context of application to risk assessments.

Questions for Jerry Bromenshenk

Q. How is the spatial distribution of activity for bees determined for a given spot?

A. Well, as you well know, bees forage extensively, although they do have a tendency to conserve energy by not foraging any farther then they have to. You can do this in a couple of ways. If you do a broad screen, where you are just trying to look at a large area, then we can establish sites where we intentionally overlap foraging areas. That's what we've done for example in the Puget Sound area. We have a paper in Science that deals with that. If you are dealing with a more localized area you can look at what crops or plants are in blossom. You can pick up a pollen sample at the hive, look at that sample and know exactly what plants they've been to. Now, if Oak Ridge National Laboratories gets additional funding, we'll actually be able to follow a bee, because they've already got an infra-red transmitter that a bee can carry. We just ran out of money before they could get an affordable receiver.

Q. I read somewhere that they were putting little coding strips like they have in the grocery store on bees.

A. That's a mark-capture-recapture procedure that Jerry Loper at the Tucson Carl Hayden Bee research lab came up with. He actually got an award from Mechanix Illustrated for the most unique technology. Unfortunately, it doesn't work. The bar code reader has to have a unique orientation, and the bees don't cooperate well enough in terms of how they go in. There are ways to mark bees, though, using a little magnetic tag. We've done that for a long time. You catch them out in the field when they are foraging, glue a little magnet on them and attach a giant magnet back at the hive. When the bee flies in, he gets caught, wiggles around a little bit and the bee drops off and the tag remains behind.

Applying Risk Assessment to Ecological Communities[1]

an edited transcript of remarks by

William Cooper

Chairman, Department of Zoology, Michigan State University
Member, EPA Science Advisory Board
Chair, Ecology and Welfare Subcommittee
of the
Relative Risk Reduction Strategies Committee

This morning I discussed the risk assessment approach adopted by the Science Advisory Board's Subcommittee on Ecology and Welfare (the committee). This afternoon I will talk about some of the methods of actually implementing risk assessment from the point of view both of ecology and the welfare economics component.

You will remember from this morning we were asked not only to do ecological risk assessment, but also welfare risk assessment and somehow put the two together, actually combine the two evaluations in terms of ecological versus human impacts, the logic being that if the scientist can't do it, the politicians and lawyers will because they don't have a choice. Someone is going to have to integrate that information, to figure out the priorities as we reallocate our effort [to reduce the risks we incur from human activities.] I will discuss how we did this, and include some of the comments I heard from the speakers this morning. As ecologists we don't always look at things the same way that the general public does. I'll use some examples I've heard to illustrate that.

I said this morning that the committee was very dissatisfied with the original structure that they started out with in terms of ecological risk assessment. Well, they totally rebelled at the way economists do business. They had absolutely no desire to go through and critique the normal type of economic analysis of basic ecological resources. There is such a big difference in the way economists think and the way ecologists think in terms of looking at long term commitments to natural resources that they are two completely foreign languages with almost no overlap.

Now, this sounds kind of abrasive, and the Science Advisory Board (SAB) traditionally has been a non-combatant, non-abrasive kind of organization that tries to write documents that everyone can agree to. We were accused of being anarchists, but quite frankly, made a very strong argument that this was the one forum in which you could challenge the economists' way of valuing environmental resources, because for about 50 years we have been sidestepping that issue. Can you go out and do economic cost-benefit ratios, of any kind of credible sense at all, when you're talking about the future allocation of scarce natural resources? It's not a new field. I've spend a lot of time arguing about this with economists over the years, and the typical attitude is, Cooper, you're a good guy, but you are a very slow learner. And basically, they have a paradigm that they don't want to give up, because they can parametize it. They can come up with numbers, and once they come up with a number they are socially safe, in terms of making any qualitative judgement that they can be criticized for.

In the same way I've heard people this morning say we've got to come with numbers on risk assessment. Once we come up with a number somehow it's more analytical, it's more defensible, it's less value-driven. And yet you know as a scientist that those numbers are purely generated, with no value to them whatsoever, that you are deluding yourself to think that a good qualitative gut judgement isn't better. It makes more sense. It's probably more defensible.

It's really become a basic intellectual challenge, and so we threw down the gauntlet, and the economists picked it up, and quite frankly this is the most contentious thing we did. We are forming a committee now, at our request, through the SAB, to see "how you do this if you gotta do it."

I had an eight member task force, and there were no economists on it, not be default, but by design. You might say that this is an arrogant attitude, but the position is, you want to combine ecologic risks with welfare, with economic risks. We know that you can't re-design the time-space dimensionalities of ecological feedbacks. We can't re-engineer geo-chemical cycles. You can't speed up the rate of succession. As far as we know, you are not going to speed up the rate of evolution, which is the normal feedback mechanism that gives you repair, mitigation that takes care of major disruptions.

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[1] The following is an edited transcript from a tape recording of Dr. Cooper's remarks at the conference. The editor accepts responsibility for any errors or perversions of meaning. - Michael Marsh.

This means that if you are going to do an analysis because of long-term externalities, of negative feedbacks, coming through either a biological loop or a geo-chemical loop, you are going to have to do your economic analysis in the same time-frame that we do our scientific analysis, and since we can't change those, there is nothing the ecologist can do. The economists are going to have to redesign the way they do business. And I don't need an economist on the panel to tell them that. That's a physical constraint they are going to have to learn to adjust to, so that's the very kind of single minded attitude we took. From a physical scientist's point of view, that makes an awful lot of sense. An economic system is man-made, it can be man-re-made. In ecological systems we have very little ability to redesign some of the spatial and temporal characteristics that we are dealing with.

What are the characteristics that make our economic system ill suited to the valuing of ecological resources? We listed about 5 points in our report.

First of all, the whole concept of discount theory. This concept says that natural resources have less value in the future if you don't use them today, it's a lost opportunity cost. The concept that a biological resource or landscape, just because humans have no way of assessing value, not only does it have no value, but it degrades with time, is nonsensical. You get into that kind of mental trap when you look at resources as a surrogate for money. This mindset says that if you harvest resources now and invest the profits in the bank, with compound interest, then you are going to make more money than if you harvested them ten years from now. It's as simple as that.

If you look at environmental resources as capital, not money, you invest the capital so you have sustainable flows of goods and services for your grandkids' generation. You don 't need to show benefits today. You won't live long enough to see the benefits. That's why we invest in R & D in industry - so we can be competitive with the Japanese two generations from now. You don't have to justify it on short term yields. Just that one concept alone. If you could just get people to thinking in terms of air and water and biotic resources as environmental capital, as infrastructure - infrastructure so that you can maintain either a high quality of environmental health, or a sustainable level of economic activity. You require that infrastructure to be stable in time. That's what sustainable development means. You are not going to maintain either an economic or a human health quality system without a sustainably high quality environment.

I was on the team that went over to Poland a couple of years ago with several people from EPA. We were asked by the Academy to go over and assess the air and water pollution problems in Poland. It was before they tore down the wall. It was my first experience in recent years over there. I came back and I was appalled. Poland was the worst polluted country that I have ever seen in my life. 40% of the cities did not have primary sewage treatment. They have two rivers, and about 80% of the surface water does not even fit the lowest water quality criteria. It's in a category that you can't even use it for industry without pre-treating it. I mean I'm talking about a real cesspool, because they didn't even put a single dollar into environmental infrastructure. You are not going to re-build Poland until you re-invest in the pipes and valves that it's going to take to have something to build on. It's as simple as that.

First of all, this whole concept of discount theory is just turned around backwards. You are talking about a stewardship mentality, not an ownership mentality. There's a whole lot written on this. We run environmental criteria(?) in Michigan on a public trust doctrine. You don't own water in my state. That's the public domain. It's not even stewardship, it's user rights. You have to put it back in the same river in exactly the same quantity and quality that you got it, downstream riparian owners have the same rights that you have. That's what you mean by sustainability, and it implies a completely different ethic in the way you look at the management, the ownership, the long term obligations, and the evaluation of the value of resources. They have value intrinsic to themselves. Whether you use them or not is quite immaterial. Whether you know how to value them or not, is quite immaterial. Now that's not a trivial challenge to an economist.

The second characteristic is basically the whole concept of multipliers. They are applied in a one-sided manner, in that multipliers are used to calculate benefits, but never to calculate risks. I chaired the environmental review board for the state of Michigan for 14 years under two governors. We ran all the public hearings on all the state and federal EIS's for the prisons, incinerators, landfills, all the contentious issues. I sat through several hundred of these debates. As an example, General Motors wanted to build a Cadillac plant in downtown Detroit. They kicked 6,500 people out of their homes, and justified it economically. The city gave the land over to GM so they could keep GM in Detroit and keep competitive with the Japanese. The whole argument was in terms of economic benefits, and they used a multiplier of 4 to 5. General Motors proposed to spend some 200 million dollars building a plant. Coleman Young justified it economically terms of public funds; he multiplied it by five, and said the real benefit was five times $200 millions, because he calculated all the secondary and tertiary benefits, and all the spin-offs, the garages and mechanics and restaurants that support the laborers.

But when you get around to calculating the economic dis-benefits, the environmental impacts of development, I've never ever seen them use the same logic. When we used kepones on the James River in Virginia, the dollar value of the kepone and the loss of the shellfish, fin-fish and the crabs in the James River was stated as the dollar value of one year's crop not sold. They didn't calculate the outboard motors that weren't made in Wisconsin and the fishing lures that weren't made in Chicago, and the refrigerated trucks that couldn't take the jimmies up to the bars in Maryland, etc., etc. It's a-symmetrical, and as long as you allow that to continue you are always going to underestimate the environment. Reduce it to nothing in this generation and pass the real loss on to the next generation. It's bad economics and bad ecology, because it's a-symmetrical.

The third big challenge that we had in risk assessment is the way we go about valuing, and who is to pay, for the use of goods and services from natural environments which traditionally have had no value put on them. Almost all those goods and services are outside the marketplace. Those bees that are pollinating your flowers, the bacteria recycling your pesticides in the soil. Your plants recycling CO_2 into oxygen. Those are what we call free goods. They are non-market goods and services that humans take for granted. You couldn't live without them and you don't pay a dollar for them.

How are you going to put a value on something that's outside the market exchange place. The only way you can do it is to have the concept of willingness to pay. The value of a fish is how much someone is willing to pay to go catch one. The willingness for you to go out and enjoy a national park without impaired air pollution - without impaired vistas degrading your experience. It's how much time, energy and money you spend to go out and look at it.

Now, that's got all kinds of problems. It can give you a number. You can generate a number from it. We can go into court and we argue the dollar value of a fish in a pollution case - it's crazy as a coot, because it's entirely prefabricated numbers. You can even go so far as to estimate the value of an alewife that some pump-storage unit chews up. Now an alewife doesn't have much value. It's a grubby little fish about that big, but if you calculate how many alewives a big salmon has to eat to get big, and how much you are willing to pay to catch a big salmon, and back-calculate, you can find the value of an alewife. I mean, you go through all kinds of convoluted, crazy, estimates of dollar values.

So, first of all, they are surrogate values at best. There is no logical basis for them. The second thing is, I don't really know how people can know the value of a resource until you lose it. A concept in economics is, as the scarcity goes up, the prices go up, and you shift to an alternative material. The concept is you can substitute! When you start talking about groundwater, or air, or food without toxicants in it, you don't have the ability to substitute. There are certain kinds of ecological amenities, or goods and services, for which there are no alternatives. So what happens to the value of a substance? The value as it grows scarce goes to infinity, doesn't it?

People asked why we valued groundwater the way we did. Groundwater comes out on the bottom of our list ecologically because there is no exposure. When you pollute groundwater, it comes into contact with some anaerobic microbes, but there's no biology down there to speak of. Oh, there are some insects that live down in the gravel, but not in terms of any major exposure. By the time it comes to the surface it's usually in an up-welling area, and there's such a dilution factor, once it comes up in a river course or goes out in the Great Lakes or Chesapeake Bay from groundwater, that you can hardly even pick it up. Any time you find a pollutant in ground water, at least in our state the first thing you do is come in with federal or state superfund money, slap a fence around it, put in an alternative water supply, and you can't even show human exposure.

So the whole argument is, what we are going to do is preserve groundwater as a potable water supply for future generations. So where should it show up? It should show up in the welfare analysis as a high priority thing shouldn't it? Cause the benefits aren't for today, we can still substitute today, at least for a while. Most people aren't drinking contaminated groundwater for very long, at least where I've worked. You sue the industry, they bring in a pipe, no mater how far it is, and put you on an alternate water supply. But when it comes putting a value on it, groundwater doesn't show up, because if you discount things at 3% a year, and if you don't need that groundwater for 20 years, it's got no value. You are in a catch-22 no matter how you do it.

And that's why [in] every one of these analyses, whether Human Health (subcommittee) did it or we did it, groundwater is an outlier. You want to jack it up there, because most of us have spent most of our professional lives trying to protect groundwater. That's how a lot of people started in this business. And it's really tough to go out there and say , on hard data, if you really want to talk about risk, it becomes a non-issue. It's not a non-issue politically, and it's not a non-issue in terms of good management of natural resources,for future options, we're fully committed to that, but try to show it in good hard dollars and cents.

This is causing the water people at EPA to have real heartburn right now. Cause if they shift over and start doing this on real performance criteria of reducing risk, how can you reduce risk if you don't have any exposure to start with, and so I point this out as a real battle; we haven't resolved that one yet. Just so you know where everyone is coming from.

So we threw out traditional economics on three issues. And if you do that, you are going to have to come up with an alternative. So this is an ecologist's alternative look at welfare economics. This is what we gave them. We said you can throw it out, modify it, tell us what's wrong with it. At least it's a way of keeping the dialogue going. So it wasn't all negative.

We actually defined four kinds of welfare impacts if you are looking at risk assessment.

1. The first one was ecological quality. This has to do with the use of biological resources [through] direct consumption by humans. I mentioned this morning the PCB's on the fish in the Great Lakes, the salmon. They don't kill the fish. You cannot show any ecological impact on those fish at these concentrations. It's somewhere between 2 to 5 ppm (parts per million). Even up to 10 to 15 ppm you couldn't show biological effects., but since the action level for PCB is 2 ppm, for the last 10 years we've buried every salmon we caught in the weirs in landfill. That is, the biggest impact has been economic, not ecologic, on humans. That's a welfare impact, on humans. It's modulated through an ecologic process, food chain accumulation. So the stress or the risk to that is an ecologically modulated effect. I can calculate the risk just as I can calculate any type of ecological risk. I'm adding apples to apples. You can put it into a context in which you can make them be one and the same kind of analysis.

In fact, if you look at it, the vast majority of chemical pollution events, like kepone, like PDB, like PCB's, the mercury, Lake St. Clair, for every single one of those you can't show long term effects on ecologic resources. The bulk of the thing is an interruption of economic use of the resource. It's not a biologic degradation of the resource. It's not a degradation in the sense that there aren't reproductive populations. I'm sure they are down in numbers, and they are sick, but even at the height of kepone in the James River (it's one of the most toxic of chemicals, and we got about 80,000 lb of it in there), every species that was supposed to live in the James River we found living there. And they're coming back. The kepone is now getting buried in the natural sediments; in fact, the striped bass are better there than they ever were.

So if you really look at it, one of the biggest impacts in terms of risk is not necessarily biological, because what's happening historically, is that EPA has been sort of a quasi-public health organization that started with the assumption that if you protect public health you will protect these resources by default. And oftentimes they have, because they set the numbers so low, with their various safety factors and their various kinds of risk assessments, based on human health, that the numbers are way below lethal level for organisms. The only exception to that, that I've personally worked with is tributyl tin. TBT is the first chemical that we banned. EPA didn't ban it, the states did, because EPA didn't move fast enough. Michigan was one of them. Virginia started it. The first chemical that was banned strictly on ecological data alone, without using human health as a surrogate argument, was tributyl tin. It is toxic as the devil, and it makes female snails turn into males

(tape turned over here)

economic impact in terms of degradation before you see the species gone, all right?

2. The next one, resource sustainability, deals with a structural configuration. This is what you mean by biological diversity, conservation biology. There are certain landscape attributes that are not only biological, a big trend now is landscape ecology. There are also things such as size and spatial layout of these biological things that make landscape ecologically stable. This is what you mean by sustainability, from the point of view of the environment. It's a perpetuation not only of the individual species, but their spatial distributions, because as they interact in time, the probabilities of their interactions are the spatial distributions between them.

There is a whole area of landscape ecology right now that says you can't do your risk assessment just by looking at a population. I just came back from Florida and a meeting with Larry Harris, who wrote the book on the fractured forest out here in Oregon. and we went around the Everglades. Florida had just passed an amazing piece of legislation called Proposition 2,000. It's a public bond issue - they are bonding themselves, and they are going to spend $300,000,000 every year for the next 10 years just buying land to buffer fragile ecological systems to protect them. They are buying lands around the Everglades to take them out of the agriculture, to keep the phosphorus from the cane fields, from allowing the cattails to take over the Everglades lock stock and barrel as a monoculture. Which is what is happening right now. The same thing in Barrier Island (?), getting corridors to connect patches, so that in the aggregate we have enough land area to support species like the Florida panther. That is, the wetlands are protected by law. You can't protect the wetlands if you don't protect the buffers around them. The wetland is not an integral patch by itself. So you have to get your risk assessment up above the individual species population.

If you really want to talk about preserving biological diversity, you've got to preserve the habitat for that biological diversity, and it's a much bigger area than people give you credit for. In fact, the original work was down here in Oregon, that Larry Harris has done, looking at photographs of Oregon as they lumbered it, where you had a contiguous forest and you started getting patches and patches and smaller patches, and how are you ever going to get that back. Well, you can't get it back, but you can hook it up with corridors, where the organisms can move between the patches until the thing is a whole, has an area big enough to survive in. This is a concept we used in Costa Rica, where they just bought the corridors to connect up the national parks, It's been used in Africa, it's being used all over the place. It's that kind of landscape perspective which lets you see the structural underpinning of the thing. If you open up the habitat you can't protect the species, whether or not you have chemical stressors. and that's that whole extra dimension of risk assessment that we talked about, that has nothing to do with command and control, what number you put on a pesticide, what number you put on a herbicide or something like that. It's more agricultural policy, it's the way you treat land. You can't separate that from the kind of risk assessment that you look at.

3. The third category basically, is what the economists have traditionally done. This is the direct economic effect, the things you put dollars and cents on. This is the effects of acid rain on the marble statue. You can calculate the cost of replacing the marble statue. That's a nice marketable good. You can calculate the cost of marble and the labor and so on, and put a dollar sign on that.

I'm not so sure where you can put the dis-benefit dollar sign, but this is where my criticism comes in about discount theory, about multiplier effects, because at least if you are going to do economics, you should do good economics. The first two are ecological phenomena, this one is a pure economic thing. And so if you are going to do it, do it right, or don't do it at all, don't even do that one. Don't do cost benefit analysis if you can't do good cost benefit analysis.

An alternative is to argue everything philosophically. Argue it all on public trust, ethics, legal protection. Make it an environmental bill of rights, where you spell it all out in degrees centigrade, in parts per million, in decibels Then you've got it cold, you enforce it, irrespective of economics. That's an alternative paradigm.

The idea about using economics is that it is the most efficient way to go, assuming that you get the right weights, the right signals, you can put the right values on things. If you can't do that it is a very dangerous way to go.

4. The last one is to me the most difficult one for you to handle. And this is the impacts that are directly on humans, not on dicky-birds and fish, but they don't have direct economic value. And this is called social nuisance law. Probably about 80% of the environmental impact statement hearings and social hearings that I've run, this is where the issues are. Noise, odors, vistas, the sensory stuff. It does not affect human health, you are not going

to die from it. You are just mad, you are unhappy, In fact, we got int a big debate over whether we should include fear and anxiety. If you are living next to a big land fill, you are not going to smell it, you are not going to see it, necessarily, if you put a fence around it, you are not going to hear it, but just the knowledge that it is there is a hell of a stressful thing to a lot of people, so we even had a big debate whether we should put that in there.

Take hydrogen sulfide. They want to build a hog hotel; 40,000 pigs in ten acres of land. Did you ever see one of those things: about 4 acres of open lagoons on a good July day? because a pig produces about 3 times the urine and feces of a human. No treatment, just open lagoons, and in the wintertime they spray it out on the cornfields. The smell is unbelievable. The neighbors were mad as could be, and these were agricultural people, mad at agricultural people. But that same chemical if you are down wind from a sour gas well, smells like profits. Exactly the same rotten egg small, exactly the same chemical.

So here you've got exactly the same chemical, exactly the same odor, and depending on who you are, it's 180 degrees out of phase as to the perception of whether it's good or bad. Now how do you deal with a problem like that? Maybe you can't. Maybe that's why you go to courts of law. But there's an awful lot of people who feel that that's the major issue, in terms of risk assessment, social issues. In fact, when the state of Vermont set up their risk reduction process that we talked about this morning - they are halfway through it, the same thing you guys did in Region 5 - they set up a committee just for quality of life. That's what they meant by quality of life, and it was the most important social set of questions that they were concerned about: that Vermont was a beautiful pristine state, and they wanted to keep it that way. And they were far more concerned about this class of impacts, of risks and impacts, than all the rest of the issues.

And that's the one that, maybe the social scientists can handle it, but it's the one that people like myself, and most of the chemists and engineers that I know, had no way of addressing. You can understand it, but how do you put any weights on it? How do you weigh whether this is as important or not as important as these things? So that's the one, I think, where you are going to have the greatest trouble. You can define them qualitatively, but to handle them in any kind of a ranking sense, I don't know.

Just a few more comments and I'll stop, because I'm out of time. One of the comments this morning was that ecological systems are basically driven from the bottom, by bacteria and algae. That's correct. We talked about it at lunch, that if you look at the energy budget of an ecosystem the vast majority of your energy goes from plants right into microbes. It doesn't go up to the animal system at all. A very small percent of it. In fact when they did the IBP budget for the grassland biome at Fort Collins, they had a great big, eight digit energy budget of calories per year going through this meter squared, and to even get birds to show it you have to be two places to the right of the decimal place, to even get them into the equation. But don't kid yourself, they have a big impact in terms of a control system modulating what other species are there.

So there are examples of top down impact. Everything doesn't come from the bottom up. I happen to be working now on Lake Victoria in east Africa, which went anaerobic three years ago, unfortunately, and we are looking at the biggest mass extinction of vertebrate species anywhere in the world. They have about 500 species of haplochromids and *Tilapia*, and most of these are mouth breeders, they are very endemic within the lake, they are bottom breeders, and the lake is anaerobic now up to about 28 meters. We may have lost about 350 to 400 species already. The whole lake now is in the Red Book of endangered species of vertebrates. We just stumbled on it by chance, in fact we've got a team over there right now, with an ROV to do some underwater exploration.

It looks like that change was driven from the top down, it was the introduction of the Nile perch there in the '60's. I went over there thinking it was Lake Erie again, with phosphorus eutrophication and agricultural and industrial runoff. It didn't appear to be, from what we could see, any of that. It looks like a top down thing. They introduced this great big 250 lb predator, riverine fish, for sport, and wholly wiped out the commercial fishery, the big tilapia, that made up the bulk of the human food chain; it was the forage base. They are all eating bluegreen algae. It's a nitrogen limited lake, not a phosphorus limited lake, so we were wrong in terms of eutrophication. And the zooplankton in these tropical lakes are little tiny things, like that, so they can't eat the big bluegreens, so the only foraging base in water column was these big tilapian fish, which are wiped out by the Nile perch. Chlorophyll has gone up fourfold in the 15 years. The bottom of that lake is 24 degrees C., so the algal rain down there has tied up all the oxygen, it's all gone anaerobic.

These are the kinds of events that you start predicting now. And actually if you look at that kind of catastrophic impact, almost every one that I know of has not been chemicals, it's been biological introductions. The alewives and sea lamprey in my Great Lakes, the Nile perch over there, the kudzu weed, the nutria in the cane fields in the gulf, you can go right down the list, and actually we've done far more damage in terms of ecological structure and long term damage impacts on ecological landscapes by biological introductions than with all the chemicals summed up. And yet that's the one thing that you very seldom ever see in environmental impact or risk assessment. Probably the biggest thing your chemical stressors do is weaken structure of the system such that it increases the probability of an exotic introduction. It's the exotic introductions, the secondary impacts, that do most of the damage. But that's an area that I don't think I've ever, in the hundreds of EIS's that I've looked at, even heard discussed, in terms of secondary impact.

With that, I think I'll stop. Any questions?

Questions for William Cooper:

Q. In terms of introductions, and change in ecosystems, I've heard some rather dire predictions of what the zebra mussel might do to the Great Lakes and elsewhere.

A. Well there's no question, the zebra mussel is just one of a whole number of these things. They were dumb enough to - sterilize the ballast water, they load a boat in Germany with fresh water, and they come across the ocean, don't blow it in the Hudson River and fill it with salt water but come up to Cleveland and blow it there. It was just an accident waiting to happen. It's crazy and we've been fighting that for years, and the Coast Guard says , we don't have the manpower to enforce it. We'll make it voluntary. And you know damned well that a ship captain is not going to spend eight hours doing something voluntarily. So now they wait until you get a "60 Minutes" item. Now they have to retrofit the system and make it mandatory that they do it.

Yeah, the zebra mussel - Lake Erie is as clean as it's ever been. There's no algae left. You can see the bottom for the first time, because they just filter every damned thing out of that. So there goes the whole plankton base to support your fresh water fishery. It's one of the best wall eye, small mouth, yellow perch fisheries in North America. These things are bound to have an impact. Now, it will seek its own equilibrium eventually. But in the transition, there'll be problems; they won't be biologic, they'll be economic.

There are some ducks that eat zebra mussels. They have come up with a couple of exotic compounds that do the job now, actually tributyl tin (laughter) is the best compound. If you paint those shiny hulls of ships and those pipes and intakes with tributyl tin, you won't have anything living on them. I'll guarantee you! They've painted 5 ships from the Fifth Fleet and put them in Norfolk, which is a warm marine, highly polluted estuary, and for seven years they didn't have anything, algae, diatoms, barnacles, about nine phyla wouldn't grow on it. Shows you something about tributyl tin. There's a simple solution, but they aren't going to get a chance to use it.

Q. With regard to weakening of the ecosystem - pesticides - natural systems, the perch. . .

A. My comment should have been should have been, any stress - it could have been the effect of any stress, whether it's pesticides, thermal pollution, over-fishing, In the case of alewives and sea lamprey it was probably over-fishing, they opened up the niche. Put that in stress. Whether a pesticide is a stressor or not really wasn't the point I am making. Almost any stress, be it chemical, thermal, anthropogenic or any kind of over-exploitation, that is probably the biggest risk that comes out of it. It's almost never analyzed in any kind of risk assessment. The same thing would probably be true with your clear cutting, if you just left it up for grabs afterwards, without any kinds of control strategy. Ecological systems, if they have good sizeable endemic populations with good normal age distributions that don't oscillate wildly, and good competitive, competition is a very dominant protection. It's very difficult to introduce an exotic in a very well designed and healthy ecosystem.

Q. I don;t think the plant ecology data supports that view.

A. Well the animal data does, They tried to introduce rabbits 7 times in Australia, they tried to introduce salmon in the 1900's at least a half dozen times in Michigan, couldn't get them to take. I don't know why the plant data wouldn't necessarily do the same thing, but it's definitely true of the animal data that I know of. It's tough to introduce into a good, healthy system.

What's the possibility that an exotic species would be pre-adapted to be more competitive in a system that it had never seen than an endemic. Just mathematically that would be a very low probability, wouldn't it?

Q. A lot of vegetation is more adaptable -

A. They are more plastic?

Q. If you transport them to similar climatic regions they escape the pests -

A. Well., sure, that's true of animals too. Even with the animals the biological control is not there, but the competition still is. The only way you would find that out is to find vegetation array that hasn't been cut, hasn't been managed in terms of species composition, a little pristine one, and stick a new species in there and watch it. Most of what we are familiar with is so disrupted that you couldn't test that theory out anyway. At least in my part of the country they burned everything before they did any protection, and so the whole thing is disrupted, it's a kind of moot argument in one sense. So at best our system is bounded chaos and always will be in our lifetime. There's no such thing as stability.

Q. I think there's a difference between systems that normally are disturbed by fire, and, essentially, clearcutting, and the Pacific Northwest forests are adapted with typical species to occupy those niches after you have a windstorm or blowdown, fire. Something that basically clears the land, as opposed to a pesticide, that comes in and kills everything There's no plant, no organism adapted to take advantage of that kind of clearing that occurs with a pesticide.

A. Yeah, thats just coming out. I just reviewed a paper for Conservation Biology on a theoretical model looking at the magnitude, frequency, intensity and location of stresses in terms of stabilizing landscapes. Fires in Yellowstone, avalanches, floods, and yet you have to have both the area that instigates it, the area that exports it, and you have to have a boundary around it, and they're looking at the kind of area that you have to have to manage it, in terms of biological species. You've got to manage the frequency, the location, the intensity of the disruption. All these systems are disrupted systems, and if you try to maintain them by putting them on the shelf like Yellowstone, you are just asking for disaster. Smokey the Bear just comes out to be a bad guy.

There is a lot of good ecology coming out now about the ecology of disturbance, and most of our equilibrium is just bounded chaos. I don't mean that facetiously, they are bounded oscillations. The oscillations are important. Disturbance scrambles gene pools, It keeps age distributions from solidifying, it does all kinds of neat stuff.

Now, you can have some surrogate management strategies. pesticides might be one of them. But the surrogates only handle a suite of the impacts. Fire will recycle the nutrients, pesticides won't, but you could, in some cases will have to manage things by surrogate disruption. Because you've got so much human development that you can't burn it the way you ought to. So you will find compromises that are being made, and you will intentionally use things that have a certain amount of risk. Because the ecological benefits will probably be better. And it could be chemical disruption. So I wouldn't take that out of your repertoire as an option.

Q. You would use a pesticide that you know . .

A. Certain properties to it, but the point is there are models now that help you do that assessment, that management assessment ahead of time, they are getting better at it. There is a big area of research now. At the Oak Ridge federal lab they have a big landscape ecology program going.

Q. The elements of welfare you have developed beautifully. Historically, ethical concepts have been developed in the case of deficiency of resources. It seems to me that you are preaching to a society that has an abundant resources. It's unfortunate that they have to wait ...

A. Until they don't have any!

Q. . .do you think there is a hope?

A. Oh, yes, there's always hope. Lets face it, We have a society in our country that - I'm one - wants to be spoiled brats and be absolutely risk-free at the same time. If you can get away with it, why not. They aren't going to give up that unless they know they have to. So, that's part of the education process. The more important question is, what do you do with China, with 1.3 billion people that are poor? Do you want them - well, yeah, it's easy to say, don't do what we did, stay poor! That ain't going to sell, buddy! You better come up with a few better scenarios than that, because 80% of the world's population is poor, and they know how we live, and they want to catch up. And their attitude is, we'll do what you did, and the hell with the environment, and we'll pay for it when we are rich. Or you better get ingenious about how you get us there - you guys pay for it - that's what happened to CFC's.

They said they would take the substitute as long as we develop the alternative and gave it to them patent free. They would use them, but they can't afford to do the R & D themselves. You are going to see a lot more of that, the westernized countries developing the alternatives, and giving them to these people, because we are all going to be in bad shape if they don't.

If you take these risk curves we have here, and if I put China, Bangladesh, Pakistan, India in there it blows all these numbers right off the map. Everything you do is cosmetic, if we put them in the same equations of production and discharge that we use, and that is an underlying problem that everyone is going to have to face.

Risk Assessment Workshop

William Cooper, Chair

[Note: "Q." denotes audience comment; the speaker's name is given if identified.
"A." denotes comment from chair. This is a SELECTIVE TRANSCRIPT.

Q. What we've been talking about is, what is eco-risk? Not concentrations of pesticides in fish tissue, but, when people do ecological risk assessment, what are they trying to accomplish? What is the goal?

A. I don't know any pat, bureaucratic answer, but the answer to the question, what are the significant ecological risks, is in the eyes of the beholder in terms of what their concerns are. In terms of purely ecological impact, Number 1 in ranking of risk is the loss of a species, because it's an irreversible event. In terms of relative ranking, the loss of biological diversity is the worst possible event.

Q. But if it's irreversible, then that's not a risk!

A. No, the risk is an in the middle thing. If you look at the major reason you lose species, it's habitat destruction. Like the systematic draining of wetlands, it's an integral, additive thing, and no one can tell you when the last acre you add is going to tip the balance and the gene pool is too small to recover. You have to back off early in the process of destroying wetlands, and decide that you don't want to wait until you get to the threshold, but regulate while you still have a buffer. You get down to 20 or 21 whooping cranes, and you might not get back just on genetic drift alone. You have to maintain a certain genetic buffer, an overabundance of habitat, prior to when you see a catastrophic change in population survivability.

That's the worst case scenario. Then you talk, as we did today, about the degradation of the resource from the human point of view: can you eat the fish? This not a purely ecological risk, but it is ecologically modulated: bioaccumulation, feeding habits, etc., is ecological, but its impact might be economic.

The public, however, will tell you what ecological risk is, and [about] it's human impacts. They won't allow you to draw a distinction between that and purely ecological risk when you write an EIS. They want to talk about fear, anger and anxieties, and you will be dead if you say that's outside the boundaries of ecological risk assessment. They'll eat you alive!

Q. but you can do a risk assessment, and say that social and economic values are personal values. "I'll tell you what it's all about. Now you can use all those things to manage the system."

A. In your mind its a risk management problem, to get you off the hook in analyzing something. In their mind,there is no distinction between risk assessment and risk management.

[Exchange: "But, you have to separate the two!"]

A. Come on now, I think the idea that scientists do risk assessment and then hand it over to a bunch of political scientists to do risk management is wrong. Al Uhlman's (Human Health) committee was the first time the Science Advisory Board (SAB) ever crossed the line and analyzed alternatives for risk management. Now, the EPA didn't want us to do it. Many on the SAB didn't want us to cross that magic line of accountability where you are encroaching on EPA's turf. But we had a letter from Bill Reilly telling us we had to do it.

Q. But it separates the two, you say, I can explain this, but I can't explain that. You just said it; you said it's a philosophical discussion.

A. That doesn't mean you can't explain it. I said, a lot of the concerns are this NIMBY bit - this entire society has an absolute fetish on ownership of private property. If I put a psychiatric prison there, I would get exactly the same response as if I had put a land fill there. It has nothing to do with toxic chemicals.

Q. Then, if all the answers are political-economic ones, why are you doing the biomonitoring.

A. We were asked to combine the welfare with the ecological value.

[More discussion.]

A. EPA is coming out with a report, called the Cost of Clean: It is an attempt to analyze all the cost of environmental cleanup. All agencies, private and public. If you put the DOD and DOE in there, it comes to 3% of GNP, 400 billion dollars. There was no attempt to estimate benefits. It's all cost. The problem is, when they built the into the GNP. In the '80's and '90's, cleaning up the bomb is going into the GNP. Now what they ought to do is take the costs that we are incurring now, and go back and subtract them from GNP in the same years that the bomb was being built. That is the appropriate approach to analyzing this type of economic problem. Industries are now doing this on a current basis. Asbestos is an example.

Groundwater is another case. (but how can you calculate the cost?). Contamination of groundwater is the biggest thing in Michigan now, because liability goes with ownership. The banks in Michigan now are not mortgaging unless you do an environmental audit, and that includes groundwater, asbestos, formaldehyde, radon, and if it's a federally supported mortgage, you can't refinance, and commercial property is in the same fix. The costs of cleanup are sometimes as high as value of the property. Banks and insurance companies are regulating this without government regulations now. These are examples of how difficult it is to bound the risk assessment

Q. We found in our study that you can involve the public in the technical aspects of monitoring when they have a stake in the results. They begin to understand the process very well, and to tell their neighbors about what is going on.

A. I will be talking about that on a public television program tomorrow night, on "Sustainability". The question is, "what can the public do", and you find that you can get people working and doing a lot of the necessary work.

Q. It might be valuable in the EMAP program, to get support for the money that will be spent on it, to involve the public in some of the work.

Q. I'd like to get focussed on the question before this conference: we are concerned about risk assessment concerning pesticides, and how this risk assessment methodology deals with pesticides and where they rank among all of the ecological risks. I'm thinking in terms of sensitivity analysis, you've got these things out here, and if you removed them from the system, how much would the world improve?

A. I have a little trouble letting you get away with focussing just on pesticides. If you take an animal, or a plant based model, such as one based on dioxin, using a linear model, 10^{-5}, we did that in Michigan. You can go through calculating risks chemical by chemical, and the problem is, there is no risk-free system. What you really want is comparative risk. Instead of using pesticides, you might let land lie fallow in alternate years, and not drive it so hard. There are a lot of alternative practices in agriculture that you should compare the risk of pesticides against.

Q. In your program [then] you looked at various sources and media for environmental destruction and try to rank them. And air pollution came out higher in risk than pesticides.

A. Right. Our logic was that time-space dimensionality is the single most important criterion.You have things that have very long half-lives, going into the atmosphere, reactive chemicals, hydrophobic, coming down in the rain, get adsorbed into plants or animals. Just those properties alone told me they are the high-risk chemicals.

Q. Well, the trend in pesticides now is to get away from things that are long lasting, that volatilize, should we be spending much time on pesticides, then?

A. Well, you have engineered a solution, so you won't need to spend so much money on your problem.

Q. But take the sulfano-ureas. They aren't very lipophilic, don't last very long environmentally. They don't get into the groundwater, they last in the soil for a couple of weeks. But, they are put on in very low concentrations, they are very susceptible to drift into non-target areas. They can have short-term acute effects on non-target plant species right when it is flowering, or at some other critical period, sure, that plant is going to come back, a few weeks later it's going to look like a healthy plant, but it didn't reproduce, or it didn't put on any growth.

A. Even if you have a benign chemical, you need an application strategy that matches the growing cycle. Obviously, if you go and spray it while it's flowering.

Q. But your risk assessment must address that!

A: But at the level we did it, we met 4 times, we spend about 15 minutes talking about pesticides. No question, the strategy is going to have to be fine tuned. My feeling is, no matter if you fine tune it, it's not going to move major categories up and down those rankings.

Q. Getting back to strategies for risk assessment on pesticides, there are two tools that we have available. One is whether or not to allocate more resources to pesticides versus some other area, that's what we need risk assessment for. That's what "Unfinished Business" took us back to. Then beyond that there is the concept of evaluating the decisions that you make now, on when to use or not use pesticides, where to use them, etc., and we do that based on the data that we have up front. Basically it is a predictive kind of thing. So, is there a role for risk assessment in evaluating those decisions? For example, we have registered the use of disulfoton on this crop and it has been used for 20 years. Was that a smart decision?

A. There is no question that you have to make managerial decisions in EPA, particularly in the pesticides program. The question, is, what are you managing for? Are you managing to reduce risk to human health and ecological risk, or are you managing to see that people don't break the law. Think about that very carefully. I sat in an Office of Technology Assessment Committee with Bob Hunt a couple of years ago, when we were asked how to go about monitoring radio-nuclides, heavy metals, and organics in the human food chain. We interviewed all the states; it was right after PDB in Michigan and kepones in Virginia. Two of the biggest pollution cases human food chains, and neither of them were picked up by either the states or the federal government.

We went to all the state labs, and the chemists were not monitoring for these. They said, "we don't monitor to protect human health. We monitor to see that the law is enforced!" I'm a slow learner and I said, "But, they should be one and the same!"

They are not. They run their gas chromatographs for the 8 chemicals for which there are reaction levels. These are the chemicals they are legally mandated to look for. This takes up all of their energy and manpower. They have no time to look for new events and are not required to do so. So, you are asking, for an assessment to see whether a level of damage is acceptable. It's a very different philosophical framework than seeing whether an action level has been exceeded or a label direction has been violated. You don't need a risk assessment to do that.

Q. And we could spend all of our time doing that, but as a result of the gross risk assessments that have been done, people are saying that we should be putting our resources into the first one.

A. I think you should look at your gross asssessments: they were gross. But, how long are your action levels. One of them is, by law you are supposed to re-assess every three years? I think it's the action level that goes into the federal register. You are supposed to go back every three years, and update and change them, but almost never is it done. Once you get a number you are out fighting the next crisis. For instance, tri-butyl tin was licensed as a pesticide, back in the '60's. It was a smoking gun, because they developed it to kill snails in Africa, to control schistosomiasis, it was toxic as hell, and that toxicity data never got back to EPA. So one thing you might do as you have the energy and money, is to go back and re-evaluate the data that you have.

A. That leads to the question that leads up to this conference. The whole question of ecological monitoring, which is very expensive. What role should it play in risk assessment? One of the things SAB talked about was getting the most bang for your buck. Is that a wise way to spend your dollar?

A. Yes, in two ways.How do you know whether your control systems are working? The whole question of whether we are over-regulated or under-regulated. Not just in public health, but are we protecting the biological resources. There is absolutely no database that I know of that I can stand up there and say, yes we are, or no, we are not. We haven't the foggiest idea. There is no trend data, on anything that is interpretable in terms of endpoints of stress, in the non-human sector, outside of agriculture, and I'm not even sure it's there.

Q. But this will be incredibly expensive to look for stresses, look for changes in the environment. When you see changes, then you are going to have to show that those changes are due to pesticides, and then you are going to have to target to individual ones, so that you can change behavior, which might mean you can change the way a pesticide is used, or . . . Are there cheaper, better ways to do it?

A. Yeah, look at human medicine. Say you wake up in the morning, you feel crappy. You go to the doctor, he takes your white cell count, looks in your eye, runs a thermometer from one end to the other, probably does your heart rate. He makes an assessment, doesn't he. Low cost, standard parameters, fairly generic. He thinks he has enough correlates for each measurement that it will correlate with a whole suite of things. If everything is fine he says "you've got a hangover - go home." If one of those is way off the scale you go to the next tier and bring in the chemist, do the CAT scan, or whatever, it costs you a lot more money, but you already have some idea of which sub-set to look at. It's kind of a [logical] tree of decision making. They operate on the basis of, simple data is cheap. They focus a little bit more at each step, finally they open you up. Why can't you take a hierarchical approach like that to environmental issues?

A. Maybe you can. One of the things I'd like to see is a national program monitoring for ecological incidence. What I've heard about EMAP is that the idea is to go back to the same small area every four or five years that . .

Q. Well, EMAP is not exactly what we're getting at.

Q. Well, I'm not saying whether they are the same, or whether one is a subset of the other.

Q. Well, back to monitoring - you ask why it should be so expensive. One reason is that there is so much natural variability, that in order to get decent data you will have to invest money over time to get a baseline from which you can deviants. And because of that variability you can't just go and stick a jar in one time and pull a sample out.

A. Well sure, but the National Institutes of Health does that. They have a health reporting statistics set-up in this country for all kinds of stuff. They've been doing this for long enough now that they've got time trends. They do it world-wide. They put a lot of money into it.

Q. And it represents measurements worth trillions of dollars!

Q. That's what I mean, it's expensive.

A. But that depends on the scale of it. You may not have to track every disease like you do with human health.

Q. But how much will we spend over the entire United States in order to prove that there's a problem, and will you then be too late?

A. There's no way you can answer that question until you know what level of certainly you have to deliver. You have to decide how narrow the holes in your net will be

Q. But this is one of the things we wanted to discuss, that is, can this be done, is it too expensive, are there tools? So we shouldn't just shout down those questions.

A. Are there alternative tools; is there a better way to spend your money?

Q. And they are already spending, up to $50 million per chemical to register them, that's at the front end. Is that the best way to spend the money? I know it comes from the registrant, but it's a societal cost.

A. Yeah, you are putting an awful lot of money up front. It figures that there are really only about 5 crops that are big enough that it is economically justified to build a new insecticide for.

Q. If we put $50 million per chemical at the other end, that would be an awful lot of information!

A. But the problem is that you cannot justify asking a registrant to do a lot of monitoring unless it's his chemical alone, not generic.

Q. But lets keep in mind, you talk about high cost - we are spending a lot of money already, so lets keep in mind that we are spending a lot of money already, and are we spending it for the right thing. Maybe we need to put efforts into exactly that change.

Q. There are discussions of that kind, and this is somewhat the basis for the idea of registering pesticides conditionally upon monitoring in the future, that the registrant may have to prove that his pesticide is not [? ? ?]

A. Sure - with air emissions from incinerators. There is no way you can predict ahead of time what the emissions will be, because it depends on what you put into them and on the manager. So we put them, in, we monitor the hell out of them for the next 6 month, and them we set the standards depending on performance.

Q. The NPDES permits do a lot of that

A. Yeah.

Q. But there is some tradition established. If you tried to change the way pesticides are registered, there would be so much screaming. That would be a hard thing to sell.

Q. We almost don't have enough data to register pesticides now, with how much people want to know ahead of time. (discussion)

A. Getting back to your risk assessment, I think that you need to get out of the bind of just doing chemical comparisons. If you stay in that bind you never will find a solution. the risk, for instance, to public health I've seen figures, and this is assuming that 80% of the pesticides applied isn't to grow crops, it is cosmetic, it's so food looks nice, it has nothing to do with risk to public health.

Q. You mean, try to get people to buy blemished apples?

A. They do, all over the world except here they do!

A. It is disease free, and you can cut those spots out, there is no disease whatever in an apple worm.

Q. Apples are one thing, but the brown spots on a banana! (laughter)

A. There are other control systems, You don't need to get locked in to the idea that people have the right to have what they want.

Q. This morning you made some comment about the exposure of polluted air(?) versus ground water. I'd like to understand better your point of view on that. I understand the notion of (?). Considering the widespread distribution of ground pollution, and considering that we already have several decades of better understanding of air pollution, but we are just beginning to understand . . .

A. I think the atmospheric guys would argue with that,

Q. you also mentioned this morning about the time lag: If you look at the concentration levels in these widespread distributions of wastes, they are four or five magnitudes higher than in the air, and if you look at time lag, they are also four or five magnitudes slower in spread or degradation. We are looking at (potential) disaster.

A. But that's the point I tried to make. It's a Catch-22. The assessments now in terms of risk are real now in terms of global distributions of certain kinds of things, and populations exposed. The groundwater is an example of your terrestrial component. It's a major issue waiting to happen. In terms of transport and fate, and since we have substitutes right now in this country. At best that disaster won't show up for 20 to 30 years. The real cost of ignoring ground water won't show up for a couple of decades. And the landfills, every one of them is licenced by state government. That was the way we did business in the '50's and '60's.
When you use the kind of economic analysis where you use discount theory, you price something out. It's not real, you don't need to worry about it now, you can let your kid worry about it.

Q. Isn't that the same issue, about factoring those future costs in today?

A. Yes, it's whether you ignore it and let your kid pay for it, or take care of it now, as the cost of the cost of doing business. My attitude is, you pay for it now. But if you go through the numbers generation (discount theory), the numbers do not come out that way. Our policy says it is the number one priority, but the numbers say it isn't, it's way behind air pollution and so forth.

Q. You are saying EPA isn't doing this correctly?

A. No I'm saying from my point of view, I can't walk away from groundwater. I have a certain commitment to your grandkids. But you still have to face up to certain things today, and the atmospherics, indoor air, are way out in front. Global chemistry - for the first time in history we have enough industry to affect global chemistry. Unless you look at Poland - if you use Poland as your baseline, EPA has been 100% successful.

But we were given the task of not to say whether what you do is good or bad, but, given the problems you have solved, what are the risks that are left. That assumes that the problems that you solved will stay solved.

End of TAPE

Q. I still don't see why you still have to spend money on air, when you admit that the ground problem is a problem. (question simplified)

A. But we haven't even started to spend money on air like we have on the surface water and ground water. . . It's because we are seeing global atmospheric chemistry change! That's an awesome observation.

Q. What do you use to support that observation

A. CO_2 There's no debating CO_2's gone up about 30% in 80 years. Nobody argues about that, You can argue what it means, but you've got good hard data that we are affecting global chemistry, We are not doing that in terms of surface water. You can't show that even in the ocean. You can show it in terms of CFCs and chloride compounds and ozone. This is the first time any human population has been able to show global atmospheric change. And you combine it with, what's the name of that report you just released, on mass loading that came out about 4 months ago? That report on chemicals industry by industry?

Q. The TRI's

A. did you look at that data? A lot of surprises. In My state, Kellogg's and Upjohn - boy, did they start scrambling;. They were the two biggest point sources, and nobody knew it, and it had a hell of an impact on them.

Q. Well, that indicates there is a problem, monitoring the atmosphere indicated there is a problem, and the big question is, now that we know that there is a problem, what do we do about it, how do we change it?

A. Well in that case, public knowledge alone did it.

Q. But in that case it was point sources, but when you look at all the other sources, do those even begin to compare to automobiles. If you want to save the earth, where is the source of that CO_2?

A. It's degradation

Q. it's in power generation and transportation.

A. Let me tell you about what you get into with global warming. I went to a briefing for Senator Bradley, explained global warming from an ecologist's point of view. Then an economist came in. He said, Global Warming is no problem at all. The only sector of the economy affected by global warming is agriculture. Agriculture is only 3% of the GNP, so it's trivial!

And there's a whole sector out there that don't believe either global warming or groundwater is a problem. They can't visualize the impact that growing CO_2 levels will have, which will be total destabilization of the economy.

Q. But you still have to put the emissions of one plant, a point source, into perspective.

A. Well, we did, Air and Toxics is right up there next to global warming in our priorities. But we don't look at whether it is point or non-point - that's your bureaucratic approach. We look at atmoshpere vs. surface water vs. ground water.

Q. This is very interesting but in the few minutes we have left, could we get some sense of this group, is there any need to put any resources, any people, into trying to assess the effects of pesticides. Into trying to get data after the decisions are made.

Q. I think it's a question of a system of tiers of monitoring studies. You can start off with what EPA does today. They require some acute studies, and when required, some chronic studies. What can you do beyond that? You can go for some poisoning studies, some bird kills or things like that. You can go much more expensive. For example, you can try to catalog ecological systems, to look for a baseline to try to attribute changes tc pesticides or other things. You could try a pilot program in a small area before doing something on a national basis which would be incredibly expensive.

There's a process that you have to think about. In an ideal world where you have lots of money you want to go for broke and try to do everything you can to look for ecological changes.

A. Well, why can't you use existing data bases like HEALTHNET? Food testing agencies like FDA do a lot of monitoring for pesticide products in food products.

Q. That's what I'm saying. before we go out and get more numbers, lets look at what we've got now.

Q. We are actually doing that in the Northwest. We are trying to get a handle on all that is going on right now, and we have a contract out, the contractor is trying to assemble all that information and make it available to everyone.

A. National marine fisheries has a bunch of stuff on seafoods - done with standard analytical procedures which have been going on for 10 or 15 years. There is a bunch of stuff out there.

Doesn't it seem as if we are being pushed into this pesticide bit? If Region 10 wants to go out there and start monitoring, then I think that is a worthwhile thing to do. But to start out and say it only for pesticides, puts us into this little pesticides box. When you do find a problem, then it is going to be difficult to sort out and see whether it's due to pesticides or something else.

I can really see a monitoring thing to look for changes, to find things that we really haven't identified yet, like the dioxin problem. You say that the spending is something like $50 million to get a pesticide registered.That ought to give us at least some assurance, - it doesn't say that the pesticide is not a problem, but it ought to give us as least some assurance that it is not going to be major.

Maybe we're focussed on pesticides just because that's where EPA puts it's money - pesticide dollars, water dollars, non-point source dollars.

Q. Maybe to illustrate the problem: EPA did a study of acid rain, where they artificially lowered the pH of a lake to 4, and there were very few changes from when the lake was pH 6.8 or whatever.

A. Well that was John - - -

Q. The conclusion was, well you don't have to worry about a low pH., but then they saw lakes where the pH was lowered, but nowhere near 4, and it basically wiped out the biota. Well, it turned out that it wasn't the lake at all, it was the aluminum, which was in the watershed, and when the pH got below 5, it mobilized the aluminum, and that was what poisoned the organisms. The point is, you can do some really intelligent experiments up front, and but they may not take account of all of the variable, so don't we have the responsibility as decision-makers, as the people allowing the release, to follow that up with some sort of post-decision monitoring to

Q. I guess that I would argue that you have to be a little bit broader, look at a whole variety of stuff.

Q. That's more expensive

Q. Does it make sense to get concerned when a pesticide has 100 ppb benzene in it, as an inert, when we've got 2% to 6% benzene in gasoline?

A. On the other hand, the drinking water standard for benzene in Michigan is 0.6 ppb. It's a very bad actor.

Q. It's a bad actor, but where should you go after benzene. it's going into the air from the gasoline. (exchange about where to spend dollars most effectively)

Q. We're not suggesting turning a blind eye (to it's presence in pesticides), I'm not familiar with the Clean Air Act, but many of the other programs do the kind of monitoring that we are talking about right now. They make a regulatory decision that will result in the release of a substance into the environment, and they require,some monitoring to see that decision is right.

Q. That's called product stewardship.

Q. It seems to me that we should go toward a tiered information system, and it seems to me we ignore a very successful one, maybe just because I know bees better than anything else. I've learned that bee-keepers can tell you where not to keep bees, because they have recurrent problems, generally there's a problem there. Those keepers that have several hundred hives can tell you where the problem areas are. They may not know what the problem is.

Now in the tiered analogy, we know that there is a problem there as a result of the first step, then we may have to do some digging to find out what it is.

Two things come out of that - one is, that in the short term the bee keeper sees the problem. The other is that, we have found out that the more important effects are the low-level long-term, cumulative sapping of the productivity of the hives. It's different than that nailing everybody and the whole hive dropping dead. Occasionally you will see stresses building up and doing that, and this makes us different than the traditional pesticide toxicologist, who says that if it doesn't push them all over the edge, it's not important. Ecologically it's much more important, the long, slow debilitating effect. But I think we have information sources available to us, not just the acute studies, but (?) (ask other listeners)

Q. This gets back to some of those cost things - there may be enough going on already by different groups, that never talk to each other that it . .

A. Maybe we are looking at the wrong things. WE know that if we go out in the Great Lakes and get a fish that you are going to get organochlorines, and so what, those levels are declining - We need to look for the newer pesticides that are being used now.

Q. Well, we are talking about more than looking for pesticides. You take sulfano-ureas. You can go out and look for them, but you aren't going to find them, because you can't measure than low, but they have an effect. I mean, we think they have an effect, because.

A. There's whole classes of things like the organometallics - it happened with tributyl-tin, there's arsenic, cadmium, zinc, organic complexes, a lot of it's used in agriculture, the organic chemistry is not there. when the boat paint came out, we couldn't see it down there, they had to develop new techniques. There are pyrethroids, a whole bunch of things that analytical chemist can say, look out for this one.

Q. Now there's also the matter of, who's goals are you looking at it from. There was a meeting down at Reno a questionnaire came out, generated by the bee-keeping industry that was getting (beep) off about losing bees, asking "how do you define bloom", and does a week in bloom constitute a violation of the label registration. and the feeling among the state enforcement people was, for god's sake, don't classify weeds as blooms, because it will give us an impossible enforcement situation. From an ecological perspective, bees don't know that blooming weeds aren't blooms!

Q. Rick, as a manager, if someone does an assessment, what are you going to do with it. We're in a local region. We have incidence of disease, either of people or of organisms. Do you want us to assess that, help you manage the application or use, or do you want to shut down the carbofuran industry nationwide?, which is what EPA does in the $50 million dollar type thing. They are making a universal decision. I think if you do an assessment for a manager you have to decide what you are going to do.

A. (Rick) As I understand the question, what it boils down to is, if we would get information on effects of a pesticide that were not anticipated at the time of registration of the chemical, we would like to give that information back to the Registration Division, have them re-look at the registration. They may not have to ban it, they may put some label restrictions on it. They may have to change the rate at which it is applied, they may have to change the time of year, there a lot of things they could do, or, they might have to ban it.

Q. So what you are doing is validating the model which allowed them to register the pesticide in the first place.

Q. I think one of the best monitors of ecological problems is, and I think that's what I am hearing, "how do you know where they are?", is people who live on the land are the best indicators of where they are, not the transients who've moved into a townhouse last year and they are going to move out in one more year, but the people who have been there for a long period of time, who have a reasonable baseline for what's going on, for instance "We don't have birches growing here any more". Now, why is that?

These people know that there is a problem. They don't know what is the reason for that, it's going to take someone to come in and take a closer look at that ecosystem and understand that area, but if you are going to try to monitor the ecosystems of the whole United States, people who are already on the land there have the baseline information that you need. That's the way it used to work when we were doing farming with lots of sensitivity and with eyeballs and ears and noses. Most times not we have a mechanized farming with a couple of guys on tractors who are farming thousands of acres,and they haven't got time to look at anything. That's a problem when about 2% of the population is farming and there aren't enough eyeballs and noses.

Q. It's not just farmers, it's hikers and Audubon Society . . .

A. I'm talking more about the agricultural setting where we use most of the pesticides.

Q. And when we talk about sustainable agriculture, we have to get away from one person farming 40,000 acres.

A. There's a lot of technology, I had a grad student 15 years ago, Steve Welch, at Michigan State - he's gone to Kansas now, Developed a model on a PC, on Cherry orchards. You get the cherry blight in your orchard, and there's a window of temperature and moisture, and you've got 48 hrs to spray before the fungus takes off. They have weather stations over the county reporting back to a computer in the experiment station's office in the county, and he can put out an alert to farmers. Same thing with apples now.

Q. Insects in Florida come north through Georgia. The farmers in Georgia now know they don't have to spray every three days because the bugs haven't gotten there yet. They don't have to spend $2,000 to spray your field, because the southern army worm isn't there yet.

[discussion of whether it's risk assessment when a farmer makes an informed judgement, whether or not to spray.]

A. In the spirit of delegated authority, one of you is gong to stand up and summarize the discussion of this group. Do I have a volunteer? . . . You are the only one with a tie on, I don't know your name,

Q. Michael (Firestone).

A. Michael, you just volunteered to stand up and summarize this discussion.

A. Now, what are the end points of this meeting that you want him to pass out? I here some of you saying, we need risk assessment for accountability, to see whether our programs are working. Do you agree to that? To see whether you are under-regulating, over-regulating, or what

Q. You have to consider both the cost of that pesticide right now, and it's future cost to society

A. Sure, I didn't limit your time frame. One thing about risk assessment and or monitoring is to see that your controls work. What else did you agree to?

Q. There should be better utilization of the other databases out there.

A. That's correct. No sense in re-inventing the square wheel. I'll tell you, databases will eat you alive. NASA is an example of that. It gets to be the tail wagging the dog.

Q. There's an issue that we started out with, and it wasn't resolved. There's a point of view that, as a scientist you do your research, and you throw out your numbers, and you say, that's all I owe. The other part of it, and I agree with you, is that point of view is almost immoral. As a scientist, an ecologist, you come up with a function or a system or a number, you are best to know how that is to be used. And it's almost your duty, maybe that's too strong, to apply that, and get it out to the public. I've heard it said before that every scientist should spend 10% of his time putting this out to the public; we never resolved this.

A. Basically you are saying that risk assessment should involve risk communication.

Q. But it involves all the things you talked about. It involves the fears and anxieties of the people that are impacted, it involves the bees, - my father is a beekeeper, and he's not worried about pesticides, he's worried about the introduction of the African bee, whether that fear is real or not. (comment - "media hype")

Q. I think we should be careful when we talk about risk assessment. When we start doing that, we think we know what we are talking about. The world is changing day by day. We learn more about analytical chemistry, we learn more about cause and effect, we learn more about transport, there new theories about (?) which means, we've got to go back and re-evaluate, am I monitoring properly? You have to be smart, think how often you have to go back and re-look.

A. And along that line, we look about relative risk reduction. Relative means there are no absolutes. Everything is risky, there is no zero risk. Strictly comparative risk assessments, and it's residual, because you are looking for what problems haven't you solved, with your new programs. And it's risk reduction, because you are not only defining a risk, but defining it in an operational mode you can do something about. There might be some risks that are lower, but you put a priority on them because you can solve them rapidly. Radon in the basement - with a $2000 gimmick you can solve that problem. Even though it's a smaller risk than global warming, you solve it first. Those kinds of analyses are something you should be sensitive to.

Q. In another analogy to medicine, it seems to me that there are some biomonitoring measures that we can take, that are like pulse rate and so forth, not necessarily that we have to find another measure, or find the perfect measure, but find something we understand, that we can interpret, that will raise red flags.

A. If you ask an ecologist what is comparable to body temperature, that will integrate all sorts of problems or ills in the ecosystem, the only thing that is common is energy flux, like Tom Odum's kind of stuff

Q. But the big thing, why we get big horror stories like the Lake Victoria Nile Perch, is because we don't really understand how system respond to perturbation. We don't have enough information Risk assessment depends on us understanding how a system is going to respond. We tend to go out biomonitoring, and look at our organisms, clams or fish or invertebrates. maybe we need to spend more time looking at the underlying processes that support those systems, to see whether pesticides or introduction of exotic species influence those underlying processes, rather than just looking at the biota. I don't know how to go about that.

A. Well there are a lot of ways. As an example, the Yellowstone fires left a great experimental lab right now. Mt. St. Helens is another example, They are doing a lot of forest dynamics and patch succession studies.

Q. Clear cutting is another example.

A. Sure, as part of your monitoring you could look at (f?) dynamics, get a better feeling about response curves. These are all terms we use. I can use them as an academic, and don't have to worry about quantifying them. In a risk assessment, you have to put numbers on them.

Q. Should we, instead of putting our pesticide money into a new pesticide monitoring project, go out and find the on-going ecological studies and give each of them a little money and ask them to add pesticides to their monitoring.

A. That's an interesting question, because last year Bill Reilly gave all the Regions the internal flexibility to reprogram up to 20% o their budget (to confront those problems with the greatest perceived risk.)In the 10 regions, the maximum that was actually reprogrammed was 7%. (general hoo-hah) - but it's not re-allocating your money, because you are supposed to use this to monitor for pesticides, and in this case you are supposed to be monitoring for pesticides, but instead you spend the money outside of your agency, giving it to another group that is good at monitoring. This has to be less expensive and more effective. You are doing two things, you are monitoring for pesticides, and you are continuing a research project that is finding other things in the environment besides pesticides.

A. Sure, it's transfer of funds. DOE does that all the time.

Q. Pesticides rarely does that.

Q. If we did do that we'd enhance our financial synergism.

Q. I know of one instance when OPP did that, David Baker in Ohio. He has a surface water program that's gone on for years.

Q. They did that in Puget Sound before Washington state got it together and started monitoring, there were a lot of agencies that got together and agreed on how to monitor and when to do it.

A. Chesapeake Bay did some of that.

Q. To do that you need to go personal relationships between scientists. There is a program between the Las Vegas Lab, California Dept. Food and Agriculture and the Pesticide Program to develop monitoring methods and to analyze environmental samples. People got to know each other and found common problems, they shared expertise and lab facilities.

Let me ask you something. When you read the Human Health Report, Art Uhlman's report, they say that they can find no evidence of human health risks from secondary impact, that is, from pesticide residuals in food, from any of the epidemiological databases. Thee is no risk from food or drinking water. It's all media hype. The only risk was from direct exposure, to the applicators and workers in the fields. Do you agree with that?

Q. It's not that black and white, but we know that an occupational exposure to pesticides is 3 to 4 orders of magnitude higher. On the other hand, it's a smaller population, so the actual number of cancer cases due to diet is probably higher.

Q. Lets take this and study it. You know, for human health, the mode of exposure. You know that ecologically, the mode of exposure is predominantly through aquatic and terrestrial food chains. Would you be willing to recommend that all of your monitoring be focussed on those two exposure routes, and ignore trace chemistry and food products, even though that is what the public wants you to do? And ground water, because you know that your action levels are so low that you are not close to human health. Will you study only two pathways, terrestrial and aquatic food chains, mostly aquatic, because we know it's much higher than terrestrial?

Q. But Congress won't let you.

A. But that's when you stand up for your Science, and say that's what your science says.

Q. I think there is some value in monitoring foods as a preventative and regulatory thing.

A. Then let the FDA do that!

Q. But the weight of the public is against you.

A. Then stand up for your science. Bill Reilly has done that, elevating ecological concerns to the same level as human health. Don't you think it takes guts to stand up and say that to a bunch of people.? "What do you mean, dickeybirds have the same value as my kids do?" You don't know you won't win if you don't try it.

[Discussion of the relative risks of confronting the public with scientific information, e. g. "But I won't step into the ring with Mike Tyson!"]

Q. We should look at what replacements, or alternatives are available. Doing risk assessment on a lot of chemicals without looking for another chemical that will do the same thing and is a zillion times less toxic. The public wants those kinds of things in the assessment.

A. To a great degree we've done that, we're very rapidly running out of technological substitutions. Every problem we've encountered to date we've solved without a major change in life style, we've found a technological fix. We are now getting into a class of problems where that is not true -

A. You are going to have to look at source reductions

A. That's right, and when we get involved with solutions to problems that change human behavior, you are going to have a social battle.

Q. For example, people want food that is free of pesticides,

A. and they also want it cheap.

Q. We need to do better in public education about relative risk. When the Alar scare was on, there was a cartoon of a mother, driving to an Alar protest meeting, cigarette in her mouth, speeding, toddler standing on the seat beside her not strapped in.

A. With all due respect, EPA passed the buck, They should have stood up and blasted the hell out of them. If you go through life using risk aversion, you can't have it both ways. If you are conservative, no one will listen to you.

Q. There should be more emphasis on risk communication. Scientists don't want to do it, but it should be done. (Examples of scientists who preach successfully to the public - Sagan, Cousteau (his science stinks).)

Q. I think there is being better communication of science in the mass media. The ground is being prepared (for risk communication).

A. If people care, and scientists do a good job. You say everybody agrees that CO_2 is a problem. We now have a watered down clean air act. Why?

A. da da not compared to the old one. It's watered down because the political system in our country is compromised.

Q. There are some very conservative things in that 950 page document, things like keeping risk to the most exposed human being to 10_{-5}, totally outrageous conservative things that probably ought to have been withdrawn, and it's watered down in some areas.

A. Now, it doesn't address CO_2, because nobody knows how to do that today without economic chaos, but in the aggregate it's a much tougher bill than we had before.

A. But the question is, what do you want to say in terms of risk assessment. I guess what I was trying to force you to do is, if you agree that there are only two major exposure routes, do you want to limit your risk assessment to those two routes.?

Q. Well, I'll take a stand if you'll agree that there is another exposure route. In terms of ecological effects, direct application is also an important exposure route.

A. You mean in terms of loss of species, biological diversity, there's no question, we'll put that one in there.

Q. Will you restate the stand then?

A. Well,there are two exposure routes to humans, direct exposure and aquatic food chains, and the third one is loss of biological diversity.

Q. Why is it taking threats of court cases to get standards for re-entries for farm workers? I think there is more to it than identifying risks.

[tape ends while they are still talking]

Summary of Risk Assessment Workshop

Michael Firestone

The first thing we talked about was the dollars we spend to regulate. The group felt strongly that we ought to go beyond considering just what the current risks are, to what the long-term risks might also be.

We need to better utilize the current data bases before we go out and spend a lot more money trying to assess ecological health, ecological risk. Apparently there are a lot of programs, and we need get a much better system for reporting "incidents". We need to integrate the ongoing studies, to try to target where we might want to spend money in the future.

Then we talked a little about something that's making the rounds at headquarters now called product stewardship, and that means, in the case of pesticides, not just spending all this money to get your product registered today and then don't worry about it, but after you've got your pesticide registered and it is out there, working with grower groups to make sure it is properly utilized, that they don't cause either human heatlh problems or ecological risk problems. It means following up on the use of pesticides in the long run, being sure that they are going to be used safely and taking action if they are not. I think one of the things that is kind of difficult in this area of ecological monitoring is associating an effect with an agent. Is it due to the pesticides that are being used, is it due to dioxin releases that are occurring from paper mills, or whatever? And there was a lot of talk about **total** ecological health, making sure our viewpoint goes beyond just pesticides *per se* and looks at the total picture. Pesticides is obviously an integral part, there is widespread use of pesticides, of a release of something we know can be very, very toxic to the environment, but it's only part of the picture.

We talked about relative risk and the ability to effect risk reduction. In other words, if something was higher risk but we didn't think we could control it very easily, but there was something that was a little less risky, but that it was a solvable problem, and it wasn't going to be that expensive, then perhaps that was where we ought to be targetting our dollars.

It is important to use a tiered approach to generating data. Certain pesticides present a much greater potential for causing ecological risk, and if we are going to be looking for pesticides and their effects we ought to be targeting which ones. It's interesting was that there is so much monitoring of organochlorine residues in the environment. One of the reasons that OC's are no longer used is their incredible persistence in the environment. We had better go on beyond organochlorines to some of the newer pesticides, and make sure that they aren't causing the same kinds of problems.

We need to know much more about the biota and the interactions of the different organisms before we can totally evaluate some of the effects, Thats obviously going to be a fairly expensive and long range project, considering the differences across the country.

We need to use studies currently under way to look at pesticides. There are currently a large number of ongoing studies, and it may make more sense to put a few extra dollars into some of these ongoing studies and ask them to look specifically for pesticides effects rather than starting brand new studies. Cooperative efforts among scientists are important. Something that we can start to build today is interaction, getting to know who is doing what out there so that we can get some help and insight when we start new studies, or when we try to evaluate the data coming out of these studies.

OK, now we are getting to where Bill is trying to take us, which is, where are we spending our money, where are the risks: where are the real risks. Are we willing to stand up as scientists and take a stand and say, we are spending all this money in this area, but in reality, this is where we think the real risks are. We talked about retargeting money from dietary exposure, from superfund type projects, to areas where direct exposure could lead to the highest risk. I think the SAB talked a little bit about that for occupational exposure to pesticides. We talked a little bit about aquatic exposure food chain, and I think maybe that is where we ought to be spending our dollars. I think that is what we all have to ask ourselves, how much can we affect what happens with the money that is spent on risk assessment, and where to we want to target those dollars in the future.

A problem that came up is what if the solutions to the risk problems that come up require a change in human behavior. We won't really change as a society. Seems like we always look at various problems and say, well, maybe there is a way we can throw some dollars at it and take care of the problem. What if we have to fundamentally change our behavior in this country, are we willing to do that? It's an interesting question.

We talked about the role of risk communication. ALAR is a good example of [bad science education through the news media.]

The last thing that we talked about was dollars for pollution prevention, the cheapest way to affect or to reduce risk is to not have it out there.

Monitoring Pesticide Exposure and Impact in Wildlife Inhabiting Agroecosystems

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ABSTRACT

Organophosphates and carbamates are anti-cholinesterase pesticides used in large quantities on and around agricultural areas in the Northwest as well as much of North America. Their high acute toxicity has led to much concern about potential wildlife impacts following their application. Determination of exposure and impacts of these pesticides is necessary in pre-approval, re-evaluation and post-approval monitoring projects. Pre-approval and re-evaluation studies generally address isolated application sites, minimizing inputs from adjacent fields and yielding hazard approximations specific to the compound of interest. Post-approval, regional evaluations represent a greater challenge. Agroecosystems are frequently large contiguous areas of monocultured crops or can be a parchwork of many diverse crops. Potential pesticide exposure scenarios are often quite different in these assessments, resulting in impacts which may differ from those found in controlled isolated sudies. Studies will be presented which focus on both types of monitoring, encompassing corn and orchard ecosystems.

Questions for Mike Hooper

Q. In brain cholinesterase, there are reports that not only are there seasonal and genetic differences, but also there is a sampling time lag response with death to the organism for example, that the sample through time lag recovers activity. Do you find a problem like that with birds?

A. Yes, that's why you have to census your area quickly, particularly during the time when you anticipate mortality. That becomes an extreme problem with carbamates,s where reactivation occurs either within the animal or right post-mortem very quickly. Right now we are trying to find methods where we can work comfortably with carbamates, and I hope to do a field study with that this season.

Q. I think it is reasonable to find a threshold where you find tools, standard deviation - standard error of the mean, aren't you focussing on the most successful members of the community - what about the outliers? (difficulty in understanding question)

A. You pick up the outliers as that 2.5% that you expect to sit below those 2 standard deviations in your control. However, you pick up either those that are most sensitive or those that are most exposed. sensitivity may not be sensitivity to the compound, it may be a behavioral sensitivity in that the way it acts results in a larger exposure. We think that the blue jays are smart. They are the only bird that will each a whole corn kernel. They go out in the field as soon as the corn is planted, stick their beaks in the ground, and pull up a corn kernel taking the granules with it. So it may pick up individuals whether the sensitivity is biochemical or behavioral.

Q. But you have a [?], you take either very exposed or very weak animals to begin with.

A. Right, but we get past the weakest individuals as the number of individuals gets down below that threshold.

A Model for Describing Community Change[1]

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ABSTRACT

Biological monitoring and multispecies toxicity tests generate complex, multivariate data sets. The primary tools found useful in studies of multivariate data have been ordination and classification techniques based on a view of the data matrix as a collection of points in a highly-dimensioned feature space. This view usually requires making unsupported assumptions about the data (Gaussian distributions, equal variances, etc.) Where these assumptions are not met, it is often necessary to transform the raw data by taking logarithms, normalizing the variances, or eliminating outliers. We have developed a technique (Clustering and Association Analysis) that measures the strength of associations between clusters and treatment groups (or samples grouped by location, date, etc.). In our technique the data are first clustered independently of their treatment group. We advocate the use of nonmetric clustering for this step because it is insensitive to changes in scale and can filter out many effects due to outliers and differences in variance between parameters. After the clusters are generated, the degree of match between the clusters and the treatment is calculated. If the data are strongly influenced by the treatment, the clusters in the data will have a strong association with the treatment. On the other hand, if the treatment or location has no effect, the clusters will be random with respect to treatment. The strength of this association can be used to determine a significance level for the effect. We present the results of this technique on data from a standardized aquatic microcosm (SAM) test.

INTRODUCTION

Biological monitoring and multispecies toxicity tests (microcosm and mesocosm) continue to grow in importance. They address the problems of community change, and the analytical tools used to study them must be constructed in this light. Measurements on dozens to hundreds of species and abiotic parameters result in complex, multivariate data sets. The peculiarities of environmental monitoring result in problems for the analysis of this data, as well. Many species are absent, resulting in many zeroes in the data matrix. Rare species and common species may each indicate effects, although their variances are quite different. Counts may be in individuals, clusters, or colonies. Observations are quite often simply "missing" or incomplete, due to hazards of field work.

In this paper we advocate a methodology for analyzing such data sets with the express goal of simplifying the data. We want to reduce the data to its important aspects. We do this in two ways. First, the samples, which usually run into the hundreds, are reduced into a few fundamental clusters. Second, the measured parameters, both biotic and abiotic, will be reduced to a few important ones. The important ones are simply those which have the strongest association with the sample clusters. We present the essentials of our technique in the context of discussing the analysis of data from a standardized aquatic microcosm experiment.

A Standardized Aquatic Microcosm Study

The standardized aquatic microcosm test we use here for illustration involved the testing of a toxin, and also the possible mitigating effects of a bacterium which degraded the toxin. The toxin was CR, a riot control chemical, and the bacterium is known as CR-1. Questions about the SAM test itself should be directed to Wayne Landis, Institute for Environmental Toxicology and Chemistry, Western Washington University.

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[1] We wish to thank Wayne Landis , Institute of Environmental Toxicology and Chemistry, Huxley College, Western Washington University. for his contributions to our project and for providing the SAM study data.

The experiment was set up with four treatment groups, and two flasks in each group. Flasks 1 and 2 were the control group, flasks 3 and 4 had the toxin added, flasks 5 and 6 had the bacterium, but not the toxin, added, and flasks 7 and 8 had the toxin and the bacterium. Typical biotic responses to the test are shown in Figure 1, and abiotic parameters in Figure 2. As can be seen by looking at the response of *Daphnia* in Figure 1, the degradation products of this toxin were also toxic. In flasks 3, 4, 7 and 8, the *Daphnia* die out after administration of the toxin, while they show very healthy growth in flasks 1, 2, 5 and 6, where no toxin was administered. A secondary effect on the algae can be seen in the response of *Ankistrodesmus* in Figure 1. The absence of the predator, *Daphnia*, in the toxic groups allows *Ankistrodesmus* to enjoy healthy growth.

Examination of the data by eye thus reveals that although there were four treatment groups, there were really only two responses to the four treatments. We wish to find an analytical tool which will confirm this, or, indeed, reveal it in cases where it is not obvious to the eye, and also give us some indication of which species are significantly associated with this effect. In larger tests, and in field studies, the number of samples and the number of species may be orders of magnitude larger, and the overall effect may be difficult to discern.

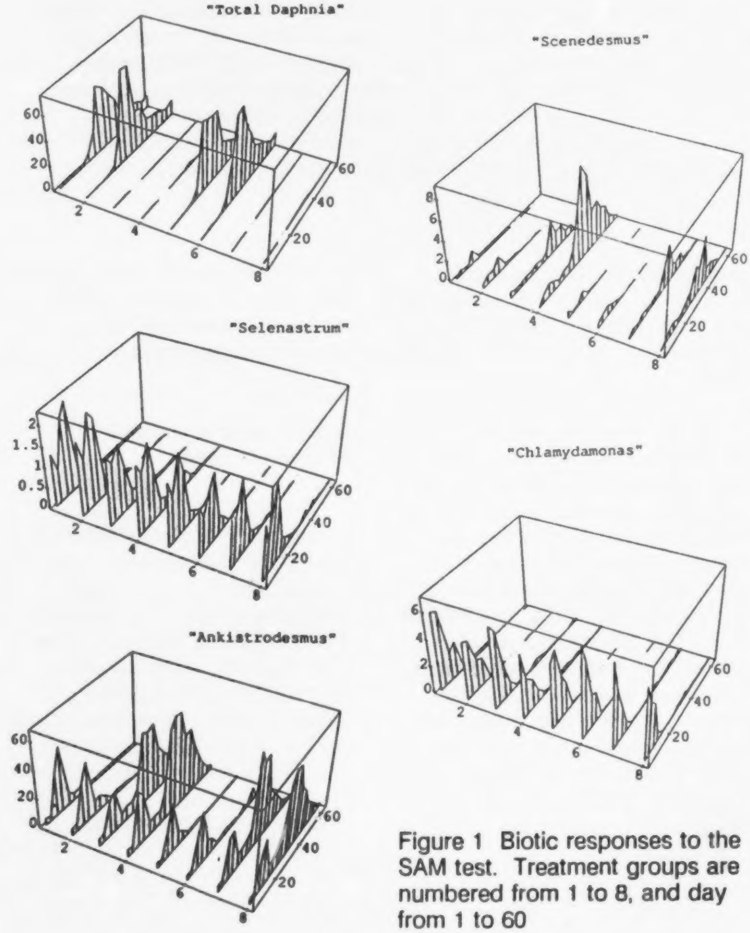

Figure 1 Biotic responses to the SAM test. Treatment groups are numbered from 1 to 8, and day from 1 to 60

Standard Approaches To Multivariate Analysis

There are many approaches to analytically expressing the observed differences between treatment groups or site locations. Some of these approaches are primarily graphical in nature, such as principal components and detrended correspondence analysis, which are designed to reduce the multivariate data to two dimensions which can be inspected and interpreted directly. These techniques, however, still rely on human judgement to determine the strength and nature of possible effects.

Another common approach to multivariate data is to try to reduce a sample, with its associated measures on many species, to a single number which combines all these numbers into one. The Shannon-Weaver diversity index is an example. One problem with this approach is simply that it often does not work. In our example SAM study, the diversity indices are plotted in Figure 3, and there does not appear to be any strong indication of two responses to the four treatment groups.

Another approach to understanding multivariate data is to view each sample, with its associated measurements on many parameters (species, temperature, pH, etc.), as a point in n-dimensional space, where n is the number of parameters. This will permit summary statistics about groups, which are collections of sample points, in terms of metric properties about a collection of points in n-space. This is the background to a wide variety of approaches, including multivariate analysis of variance (MANOVA) and an approach based on similarity measures (Smith et al., 1990). These approaches show a great deal of promise, but their reliance on the n-dimensional metric approach to multivariate data leaves them all subject to certain problems. First, there is the choice of metric function itself: Euclidean distance, squared Euclidean distance, cosine of vectors distance, Mahalanobis distance, and many others all have various features to recommend them, but the choice of a particular one for a particular problem remains a difficult decision. Second, there is the sensitivity of many of these metrics to scale. If we change one parameter, for instance, from millimeters to centimeters, we may well change important distances in n-space. If we normalize all measures beforehand, for instance by requiring unit variance, we face the problem of justifying this distortion of the data. For example, it may well be that a particular species has very small variance over all groups. We are then faced with the decision: do we "normalize" this species and magnify its variance to be in line with the other species, or do we make the decision to remove this species from the data set before analysis? Either decision has its problems. Third, there is the problem of incommensurable parameters. Most of the n-dimensional metrics require combining parameters in some fashion, for example, by summing the squares. If the data set is very mixed, however, what is the justification for combining, say, temperature and pH? How can we meaningfully sum the squares of counts for algae, fish, and clams? Worse, how can we combine biotic and abiotic measures? In any event, what do such n-dimensional distances mean?

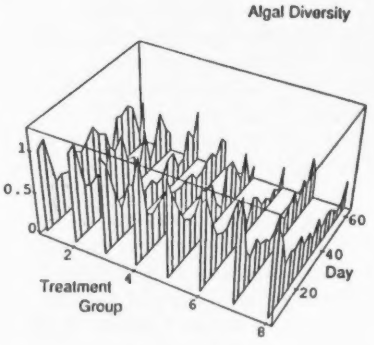

Figure 3 The difficulty with single-number indices, such as algal diversity, as characterizations of community structure is illustrated here for the SAM test

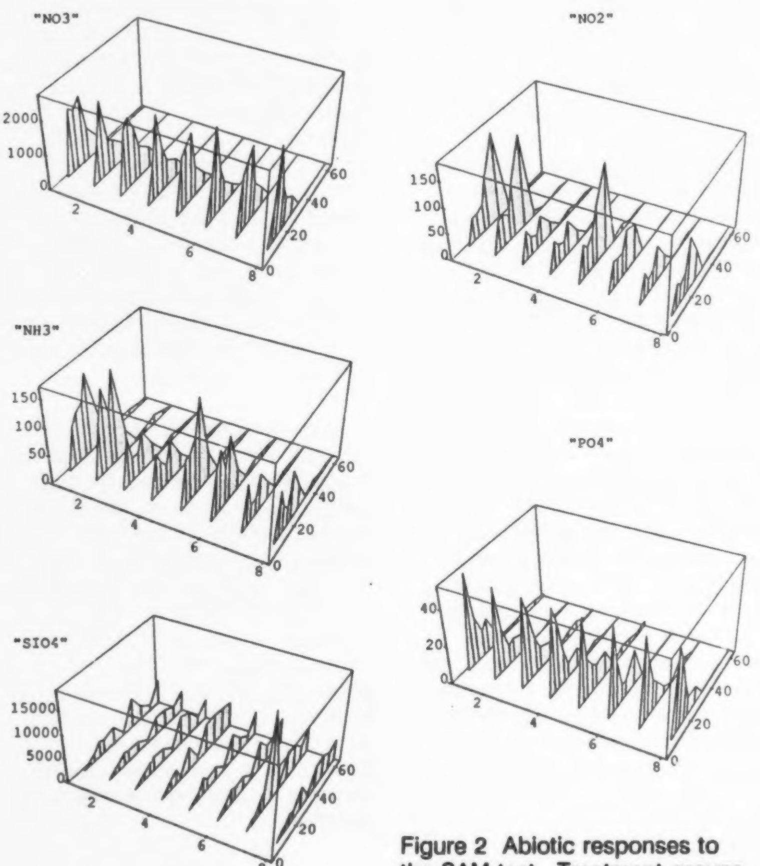

Figure 2 Abiotic responses to the SAM test. Treatment groups are numbered from 1 to 8, and day from 1 to 60

In our work we have strived to avoid the twin pitfalls of oversimplification (as in diversity indices) and a complex approach involving n-dimensional metrics which are difficult to interpret.

Nonmetric Clustering

Our approach is based, first, on nonmetric clustering (Matthews and Hearne, 1991), which we will outline briefly here. Clustering is, first, a technique of pattern recognition. The idea is that a data set of many points may contain patterns or clusters, i.e. a few sets of very similar points. Describing a data set as 100 samples from each of three clusters is simpler, and more accurate, than describing the same data set as simply 300 points. Therefore, the recognition of these patterns in complex data is paramount to understanding it on a deeper level.

Traditional clustering algorithms, unfortunately, rely on distance measures or metrics in n-dimensional space, just like the approaches discussed above. A set of points is divided into several clusters based on the criterion that the average within-cluster distance should be smaller than the average between-cluster distance. In other words, two points are "similar", or "belong to the same pattern" if their n-dimensional distance is "small". The differences between the various algorithms for clustering, agglomerative or divisive, hierarchical or partitioning, are mainly in how these clusters are found. But in each case, the criterion for clustering validity still relies on an n-dimensional distance or similarity function. For the reasons advanced in the previous section, nonmetric clustering was developed as a pattern recognition technique which avoids reliance on n-dimensional metrics.

The primary distinction of nonmetric clustering is its definition of clustering validity: a clustering of data points is good if the data and the clusters are strongly associated. In other words, if you know which cluster a data point belongs to, then you have a good idea of what kinds of data values it will have. Suppose, for instance, that the SAM data (Figures 1 and 2) were divided into two clusters, where samples from flasks 1, 2, 5 and 6 were in cluster "A" and samples from flasks 3, 4, 7 and 8 were in cluster "B". Then you would know that if a sample were from cluster "A" it would, by about day 35, have large numbers of *Daphnia* and small numbers of *Ankistrodesmus*, and vice versa if it were from "B". There may be some parameters about which you know little, for example *Chlamydamonas*, but the important thing about a good clustering is that, at least for some parameters, it gives you a good idea about the values for the points in the clusters.

We have implemented nonmetric clustering in a computer program called RIFFLE (Matthews and Hearne, 1991). This program attempts to find the best clustering for a given set of data, where best is not defined in terms of an n-dimensional metric, but instead in terms of the association between clusters and parameter values of the data points. The strongest association between clusters and parameters, for the largest number of parameters, gives the best clustering. We have used this clustering program on a wide range of data sets, and have found it to be consistently superior to traditional clustering algorithms (Matthews, Matthews and Ehinger 1991; Matthews, Matthews and Landis, 1990; Matthews, Matthews and Hachmoller, 1990; Matthews, 1988). In the case of the SAM data, a nonmetric clustering on day 35 showed that, indeed *Daphnia* and *Ankistrodesmus* were strongly associated with the best clustering. Thus, nonmetric clustering achieves both halves of the data reduction task: the samples are reduced to a few clusters, and the parameters are reduced to those few which are best associated with the clusters. In the SAM case, and in many of our other tests, the parameters selected by nonmetric clustering as the most significant are in concert with the ones a human expert would select.

Clustering and Association Analysis

Clustering is only the first step in the analysis of monitoring and multispecies toxicity test data. The clustering is done independently of the treatment groups (or locations, etc.). Clustering thus identifies patterns in the data without judging whether these patterns are due to, or even associated with, the treatment groups. The next step is to analyze the association between the clusters and the groups. A strong association between groups and clusters indicates a significant effect associated with the treatment or location.

In our SAM data, nonmetric clustering on day 35 divided the samples into two clusters, one consisting of all samples from flasks 1, 2, 5 and 6, and a second cluster consisting of all samples from flasks 3, 4, 7 and 8. In other words, a perfect division of the samples into clusters "with" and "without" the toxin. Since the clustering was done "blind" with respect to the actual treatment groups, this is a striking result. Under the null hypothesis, i.e. that the treatment had no effect on the clustering, such a match between groups and clusters is far less than 1% probable, leading us to reject the null hypothesis at the 99% confidence level.

To make sure our analysis was not biased in favor of two clusters, we clustered the samples on each sampling date into two, three, four, and five clusters. If the four treatment groups had led to, say, four different responses, then the association between the four treatment groups and four clusters would be higher than the association between the four treatment groups and two clusters. As it turned out (Figure 4) association analysis shows that the strongest association was with only two clusters.

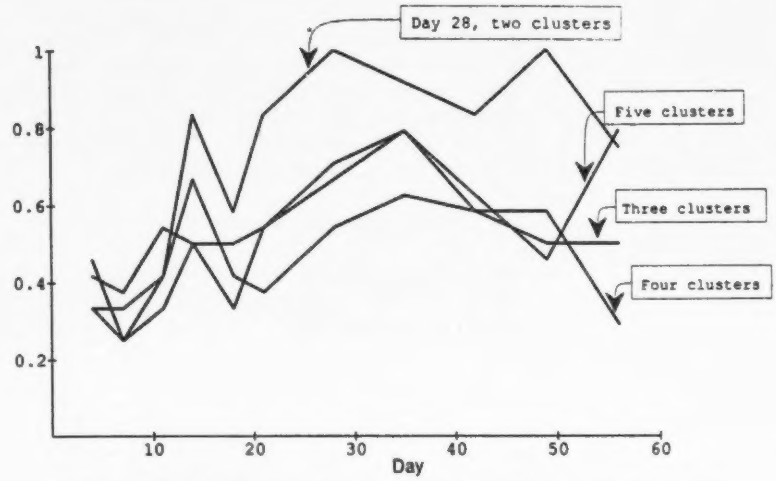

Figure 4 Significance of match between blind clustering by the Riffle algorithm and actual treatment groups. Optimal clustering is achieved using two clusters on day 28. Failure to find a significant association for more than two clusters supports the hypothesis of toxicity for degradation products.

CONCLUSIONS

Clustering and association analysis is based on the answers to the following questions:

1. Are there patterns in the data?
2. Are these patterns associated with the treatment groups?

The answer to the first question tells us whether there is anything "happening" in the data at all. The answer to the second question tells us whether the treatment groups are associated with this effect. One of the benefits of this division into two separate questions is that nonmetric clustering can be used in the pattern recognition phase and so n-dimensional metrics need not be used.

Finally, we would like to point out that traditional significance testing is implictly post hoc. It attempts to determine only whether or not a difference exists between two given populations, the treatment and control groups. If there are, in fact, patterns in the data, traditional testing will not reveal them unless they are associated with the given treatment groups. Our approach, however, looks for patterns in the data independently of the known treatment groups. This pattern analysis of the data can sometimes identify effects that the researcher did not know about; it can give him or her "surprises" and reveal new directions in research. In other words, traditional tests can tell you "yes" or "no" regarding the questions you ask. They cannot tell you "yes, but ...".

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Questions for Geoffrey Matthews:

Q. This model, is it user friendly, or do you have to have a computer degree to use it? And, is it published?

A. It is in press, to answer your last question. It is not production quality. I wouldn't be real proud of it if I released it right now. I'm not trying to hide it, I just don't want to be embarrassed when people look at my software. We are working on putting all the bells and whistles on it.

Q. Is it PC or mainframe based?

A. The search, the clustering, takes a long time. Its search takes a long time. When doing the clustering, it looks through lots and lots of clusters. You can run it on a PC, its written in "C".

Q. How can I get a copy?

A. I'll give you my card. It'll take a long time on a PC. Probably do OK on a 386.

Q. In your method, I like the analogy of putting a nozzle on a fire hose, and if you put a nozzle on a fire hose, that nozzle is metric, even though you say it's non-metric. Can your method be summarized into throttling the flow into something that can explain more things, better things?

A. There are two data reductions that are important, and they are both present here. One is the reduction of the number of variates, the number of species, from 100 down to 5, or 2; 3 in the present case. That's one of the funnels. The other is, instead of 100's of points, 100's of samples, you have 2. Even though you have 100 samples, 50 from here and 50 from here. The important difference is between this bunch and this bunch, so you go from 100 to 2. You are reducing the number of points; you are reducing the number of variates.

Q. But what I meant is, do you have a method of [?] saying, "Hah! Here it is. I didn't know it!"

A. No, then you have to go to the ecologist. I'm the mathematician. I don't do any "Hah!" stuff. All my stuff is boring. The exciting part is Wayne's and Robin's. But it does in fact lead to those things.

Q. But does it tell you whether you are right or not?

A. It does more than that. It will tell you surprising things. It will give you "A-hah!'s" You have to be a scientist to recognize them. Like the time nitrate came out. It said "*Daphnia simodesmus*", and then "nitrate". I said, "Robin, why is nitrate here?", and she said "Hmm! I'm not sure. Maybe its nutrient limiting, or something like that." So all of a sudden she was thinking about something she had not thought about before. This will tell you things that you may not have seen before.

Q. What if you change the scales?

A. You will get exactly the same results, if you change the scale on any or all of the variates. It doesn't depend on that.

Pesticides and Rare Plants

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ABSTRACT

Distribution patterns of some native plants in rangelands appear to reflect the large scale use of herbicides. Legumes are good biological indicators because they are more sensitive to herbicides than are many other species. The genus Astragalus, *a legume, is one of the largest genera in North America and has a high number of endemic species. Protection and monitoring of rare species is mandated by federal agencies under the Endangered Species Act, so additional monitoring for pesticides would be logical and cost effective. Case studies of several Idaho milk-vetches* (Astragalus spp.) *and one uncommon species of sagebrush,* Artemisia papposa, *are presented.*

Monitoring Natural Plant Community Response to Herbicide Contamination

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ABSTRACT

The limited literature on the long-term response of plant communities to herbicide exposure is reviewed. Direct herbicide treatments cause at least short-term shifts in relative composition, but diversity may decline, increase or not statistically change. Herbicide impacts are often transitory and overriden by biotic and environmental factors. The experimental design of most studies was not adequate to measure small changes in diversity. Natural plant community responses to indirect herbicide exposure are likely to be small. Monitoring efforts would have very high costs.

INTRODUCTION

Pesticide applications qualitatively differ from most industrial pollutants or hazardous spills. Pesticides are selected for biological activity, deliberately released to the environment, and well documented benefits are realized.

Herbicides comprise the largest use category of pesticides in North America. In the past decade over 80% of pesticide use was herbicides. The bulk of this use was for controlling weeds competing with crops on arable land. Only a small percentage is directly applied to natural plant communites in silviculture practices, for wildlife habitat improvements or control of noxious weed infestations. An even smaller fraction of the applied herbicides is deposited on non-target plant communities as a result of spray drift or volatilization of surface and incorporated residues.

A major goal of ecologists and conservationist has been to preserve native biological communities. Along with physical alteration of plant cover and surface soils, invasions by exotic species impoverishes and homogenizes global biota. The rate of exotic introductions continues to increase with the growth in world travel and commerce (Mooney and Drake 1986, Coblentz 1990). Eurasian plant species have been very successful invaders in the northern Rockies (Mack 1986). There is increasing scientific documention of exotic weeds supplanting native species on undisturbed sites (Forcella & Harvey 1983, Tyser & Key 1988, Belcher & Wilson 1989).

What are the effects of herbicides on plant species diversity? Could environmental scientists and plant ecologists detect the impacts of herbicides on plant communities that were not directly subjected to herbicide treatments?

PUBLISHED PLANT DIVERSITY STUDIES

Very little work has been published on the effect of herbicides on plant diversity. The available studies can be broken in to two categories. Studies which focus on the diversity of weed species on intensively managed lands such as plowed fields and pasutures; and studies which measure some response of natural plant communities to herbicide treatment of extensively managed lands such as roadsides, rangelands and forests. Herbicides are generally applied to plowed lands to kill all plant species except for the crop species. Herbicides are generally applied to non-crop lands to control a single weed species or favor a larger complex of species by stressing a smaller group.

Chancellor (1979) suggests that since herbicides have been used most frequently on arable lands that is where the long-term effects on plant diversity would be most apparent. Rather than a single weed species infesting a crop, plowed fields typically contain many competing weed species. In his review of British and European plowed field studies he concludes that there is no evidence that herbicides have extirpated a single weed in any country, although a considerable reduction in individual fields was common, or even local eradication may have occurred.

A 7 year study of a wheat field community did not reveal any change in species richness although the density of individual species changed on plots receiving various herbicide treatments (Thurston 1969). Chancellor (1985) sampled the weed species for 20 years in a pasture that was converted to grain crop cultivation. Various herbicide treatments were used on the field. An influx of new arable land weeds contributed to a peak species richness of 55 four years after first plowing the pasture. Thereafter a majority of the perennial grassland weed species dropped out under cultivation and species richness was relatively constant between 23 & 35. The fluctuation was attributed to variation in the occurrence of infrequent species from year to year. Hume (1987) determined the weed community composition of replicated wheat field plots that had received 2,4-D applications for 36 years in contrast to plots without herbicide treatments. Species abundance differed, but no species were eliminated by the herbicide.

Road edges (verges) provide important wildlife and native plant habitat in the United Kingdom because of the extensive conversion of the landscape to human use (Way 1977, Sheail 1985). Roadside vegetation was annually treated with 2,4-D at high rates (3-6.5 lbs/ac). Balme (1954, 1956) reported reduction of the abundance of dicots, including the eradication of a few species in the spray swath. Natural changes in floristic composition from year to year were as significant as the changes induced by spraying. Willis (1972) continued to study 2,4-D on roadsides for 15 years. He measured reduced dicot species richness and enhanced turf forming grass components. After 3-4 years relatively stable communities had been established and no new species colonized the study plots.

High rates (3 lbs/ac) of 2,4-D have been applied to grasslands in the western US to control gophers by reducing the dicots which provided seeds as a food supply. Frequency of occurrence of forbs was reduced while the graminoid fraction increased (Turner 1969, Tietjen et al. 1967). Total plant biomass remains the same as resistant plants utilize limiting resources previously use by susceptible species (Thilenius 1975). Discontinuation of spraying allowed the forb component to increase again (Tietjen et al. 1967). Malone (1972) reported that all species recovered sooner or later following a 7 lbs/ac application of sodium cacodylate, a non-selective arsenical, to a fescue meadow in Tennessee.

Large acreages of sagebrush dominated lands in the western US were treated with 2,4-D at 2 or more lbs/ac to increase grass production for livestock. Hendrick et al. (1966) collected data for 3 years pretreatment and 8 years after spraying. Herbage (forb plus grass) production at least doubled as sagebrush declined. On poor condition rangelands the increase was primarily from annual grasses. On fair condition rangelands the biggest increase were by perennial grasses. Evans and Young (1985) followed grass and forb succession for 7 years after control of western juniper with picloram at more than 1.9 kg/ha. Annual grasses increased while broadleaf annuals decreased.

Forest communities are sometimes treated with very high herbicide rates for silvicultural and military goals. Sterrett & Adams (1977) measured diversity in hardwood dominated forests treated with 5.6 & 11.2 kg/ha of fenuron or tree injected 2,4,5- T. The management goal was to eliminate hardwood competition to favor pine plantings. Three growing seasons after treatment 27 more species were found on the treated plots than on the untreated controls. The number of individuals of some species declined on the treated plots, while the abundance of other species increased. Shipman (1972) also reported increased species richness for a hardwood forest community following treatment with high rates of fenuron. The elimination of the overstory led to increased grass, forb and shrub production, including important browse species for deer. Species richness had doubled 5 years after herbicide application in contrast to untreated control plots.

Dowler et al. (1968) measured succession in Puerto Rican tropical forests treated with six different herbicides at rates of 3 to 27 lbs/ac. They were evaluating herbicides for the Viet Nam war spray program. Total defoliation was short lived even at the 27 lbs/ac rate. There was no definite relation between treatment and secondary succession, except that the number and frequency of successional species were greater on plots having the highest percentage of defoliation. Increased light penetration and rainfall avaliability appeared to be more important than herbicide treatment.

DISCUSSION

Poor experimental designs and lack of power to adequately test species diversity hypotheses limits the interpetation of most studies of herbicide impacts on plant communities. Pretreatment community data was usually not taken. The herbicide factor was often confounded with uncontrolled factors including differing agricultural practices, annual climatic variability and preferential grazing by livestock or wildlife. Treatments were often not replicated or too few in number. Even in arable land weed studies, which are less complex than natural communities, coefficients of variation are usually 5-10% or greater. With 3-4 replications the treatment differences must exceed the grand mean by 10% to be statisically significant (Cousens et al. 1988). Smaller shifts in diversity will be judged non-significant. The 36 year wheat field weed species study by Hume (1987) is the most rigorously designed study in the literature.

The primary objective of most studies of herbicide impacts on plant communities was not to test formal hypotheses concerning plant diversity, but rather to evaluate expected benefits from management practices. Few studies have attempted to directly obtain a measure of plant diversity such as species richness, eveness/dominance, or diversity indices such as the Shannon function. Measures of relative abundance, frequency of occurrence or biomass by life form and broad taxonomic classes were more typical. Diversity enumeration for natural communities requires sampling crews with well developed field taxonomy skills. A multitude of species must be recognized throughout various stages of their life cycles, perhaps from seedling emergence to late season dormancy. Lewis (1988) suggests diversity profiles to portray impacts of forest and range management practices on species diversity.

Ecology textbooks and environmental effects monographs (Way & Chancellor 1976, Schubert 1983) periodically cite studies which report decreases in plant species diversity in natural communities. These need to be interpeted in context of the management goals and the herbicide practices used to obtain those goals. They often have been the control of woody vegetation, canopy reduction for military objectives, or changing the forage base supporting components of higher trophic levels. These goals typically required high rates of herbicide or repeat applications. It can be misleading to extrapolate the responses of high rate applications to predict response to lower rate spay programs and drift depositon. Herbicide effects on the community are often transitory, even with high rates of non- selective herbicides.

The diversity of some communities increases as herbicide treatments reduce the density of dominant species and release limiting resources for less competitive plant species. This response is particularly evident with forest canopy reductions. Many rarer plant species only establish in shade gaps, on bare soil microsites, when moisture availability is high, and with other transitory habitat conditions. Successful exotics are pre-adapted to the climatic and edaphic conditions of the invaded ecosystems. These plants generally have escaped the grazers, insects, parasites and disease organisms that co-evolved in their native habitat. The competitive pressure from unrestrained exotics on native plant species is continuous, while stress from a herbicide exposure is transitory. Herbicide injury susceptibility ratings of plants from pot and greenhouse trials do not provide a firm basis for predicting natural community response with its complex of competing species and multiple stresses.

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Session III. Terrestrial Systems: Ann Fairbrother, Chair

A. Soils and Plants

Difficulties in Assigning Cause:
A Case Study

Karl H. Arne
EPA Region 10
(article)

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Bioresponse of Nontarget Organisms
Resulting from the Use of Chloropicrin
to Control Laminated Root Rot in a Northwest Conifer Forest:

Part 1. Installation of Study

Walter G. Thies, Michael A. Castellano, Elaine R. Ingham,
Daniel L. Luoma, and Andrew R. Moldenke
(article)

Part 2. Evaluation of Bioresponses

Elaine R. Ingham, Walter G. Thies, Daniel L. Luoma, Andrew R. Moldenke and Michael A. Castellano.
(article)

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B. Fish and Wildlife, including non-game animals.

Birds and Pesticides

Anne Fairbrother, DVM, PHD
U S Environmental Protection Agency
Environmental Research Laboratory/ORD
(abstract)

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Effects of Pesticides on Upland Game:
a Review of Herbicides and Organophosphate
and Carbamate Insecticides

John W. Connelly, Idaho Department of Fish and Game,
Lawrence J. Blus, U.S. Fish and Wildlife Service,
Patuxent Wildlife Research Center,
(article)

Difficulties in Assigning Cause: A Case Study

Karl H. Arne
EPA Region 10

Seattle, Washington

ABSTRACT

The difficulty of determining the cause of damage to plants will be illustrated by describing an ongoing controversy in Southeastern Washington State. For several years growers in and around Badger Canyon, near the Tri-Cities, have complained that herbicides applied to wheat fields in the adjacent Horse Heaven Hills have drifted and caused damage to their crops. This spring, several growers again complained of crop damage due to drifted herbicides. In response to this, Dr. John Fletcher, who is on the faculty of the Department of Botany and Microbiology at the University of Oklahoma, and who was on detail at ORD-Corvallis last summer, made a tour of some of the farms where damage had been claimed. He also toured the Washington State University Experiment Station at Prosser, where research was being conducted on the effects of herbicides to several plants. Dr. Fletcher documented this trip with pictures and an audio tape, and this information will be presented along with views of some of the affected growers and the professional staff at the Prosser station.

Introduction

For many years damage to crops in Badger Canyon, near the Tri-Cities area of Southeastern Washington State, has been attributed to herbicides drifting off the wheat fields of the near-by Horse Heaven Hills.

Reports of damage due to drifting herbicides started shortly after these materials were first used in the late 1940s. Over the years, the Washington State Department of Agriculture has taken many actions to reduce the amount of damage caused by herbicide drift. The first rule restricting the application of 2,4-D in certain areas of Benton and Franklin counties was adopted in 1953. Other restrictions in the 1950s included limiting the application of 2,4-D to the amine form or low volatile esters in certain areas, or prohibiting the use of 2,4-D in the Yakima Valley and portion of the Horse Heaven Hills. Restrictions regarding nozzle sizes, requiring dedicated sprayers for weed control work, prohibition of dust formulations, prohibition of oil carriers, prohibition of evening spraying, and gallonage requirements for both air and ground application have been put into place over the years. More recent rules restrict aerial application of sulfonylurea herbicides in parts of the Horse Heaven Hills, and have prohibited the aerial application of diquat and paraquat.[1]

These rules notwithstanding, many Badger Canyon growers claim that their crops continue to be damaged by herbicide drift. A difficulty that has arisen is that the newer herbicides can cause damage at levels so low that the herbicides cannot be chemically detected in the plants. Furthermore, for many plants the effects of these newer herbicides are not well understood. The diversified crops in Badger Canyon also make the diagnosis more difficult. The different crops show different patterns of damage and stress, making it difficult to determine any pattern that might give a clue to the cause. The damage may be at low or moderate levels relative to the ability of the plant to survive, but still quite important economically. The damage may be reduced fruit set, abnormal growth patterns, reduced yields, chlorotic spotting, and other foliar symptoms.

The Badger Canyon dilemma is exacerbated by the possibility of several sources of stress, some "natural" and some from herbicides. There also exists a seemingly endless possibility of combinations of stresses (cold weather plus herbicide A, a plant made susceptible to a virus by herbicide B, the effects of herbicide A plus herbicide B, and on and on and on).

Damage to crops because of off-target movement of herbicides is not uncommon. Often the cause can be established by detection of the herbicide in the damaged crop or by the unique symptoms exhibited in the damaged crop. Also, the damaged crop may show a pattern of drift: the side of the field closest to the source of the drift is more heavily damaged, and the damage decreases as the distance from the source increases.

However, this diagnostic aid has not been present in the Badger Canyon even when positive analyses for allegedly drifted herbicides are present. Because many farms in the area apply herbicides, and could be the source of a positive detection, it is usually not possible to link any particular evidence of herbicide contamination with a specific application.

For this conference, the interest in this situation is the difficulty in determining the cause of the damage to non-target plants, and though I'm going to talk about damage to cultivated crops, the difficulties encountered here are likely to be similar to those found in determining effects in non-cultivated areas, or natural communities. Arguably the effects in cultivated crops should be easier to discern and more likely to be noticed because of the economic interest and constant observations of the farmers.

Last spring, several growers in the Badger Canyon area again complained of damage due to drifted herbicides. About that same time Hilman Ratsch of the ORD lab in Corvallis called me to ask whether the regional office had any concerns that ORD might address. We talked of the Badger Canyon-Horse Heaven Hills situation, and agreed that there might be some possibilities for research that would help address this problem. This led to the visit of that area by Dr. John Fletcher, a plant physiologist from the University of Oklahoma who worked last summer for the ORD lab.

In late May, Dr. Fletcher visited the Horse Heaven Hills-Badger Canyon area, talked to some growers, visited the experiment station at Prosser, and documented this trip with pictures and a narrative tape. His visit was about one month after farmers complained of damage. He also visited the Washington State University experiment station at Prosser and observed some of the work being done on herbicides.

Dr. Fletcher produced two sets of slides, one showing the research on sulfonylurea herbicides being conducted at the Prosser Experiment Station, and showing crops near Benton City, in Badger Canyon, and near Finley. These slides will be shown along with some of the comments of Dr. Fletcher and of others who have observed some of the same plant damage.

Again, the purpose of this talk is to show some of the difficulties encountered when attempting to determine the cause of damage to plants. The following discussions include primarily comments extracted from Dr. Fletcher's narrative description of his visit to the Prosser Experiment Station and several area farms. In the discussion of damage to non-target crops, the comments of the Washington State University Response Team are given.[2] This is done to point of the difficulty there is in coming to firm conclusions about the source of damage in the face of a number of possible stresses. Farmers claiming damage attribute the cause to drifted herbicides, but others may determine that the cause is insects, virus, frost, disease, nutrient deficiency, or poor crop management. No attempt is made here to arrive at any conclusions about the source of crop damage.

Sulfonylurea Research at the Prosser Experiment Station

In the Spring of 1990, the Prosser experiment station began research on the effects of several herbicides on the following plants: alfalfa, grapes, roses, and cherries. Dr. Fletcher's visit occurred about one month after these plants had been treated with different levels of one of the following herbicides: Glean, Harmony, 2,4-D, Landmaster, glyphosate, and bromoxynil. The treatment rates were one-third, one-tenth, one-thirtieth, and one-hundredth of the field rate as well as control groups. Dr. Fletcher's slides showed only the two concentrations (the one-third and one-hundredth rates) of Glean and 2,4-D and their effect on cherries, grapes, and roses.

Cherries. The cherry trees used were young, not yet producing fruit. In administering the herbicides, a screen was placed behind each tree to prevent contamination of other trees, and the tree was sprayed with a backpack type sprayer. The control trees looked quite healthy, with nice green leaves, and the apices at the top quite normal looking. The trees treated with the one-third field application of 2,4-D showed considerable curling of leaves, extended internodes, and leaves at the top were not fully expanded.

Cherries treated with one-third the field rate of Glean were quite severely affected. The leaves were brown and desiccated and apparently most trees in this treatment group died.

Cherry trees treated with 2,4-D at one-hundredth of the field rate showed little effect. The trees looked healthy, and the upper branches look normal, in contrast to trees treated at the higher rates. Cherry trees treated with Glean at one hundredth of the field rate showed some effects. The leaves were a bit curled, and at the top there was some leaf damage. All trees Glean treated at this low rate showed a similar effect.

The researchers at Prosser later reported that the trees treated at the lower rate of Glean "grew out" of the symptoms later in the summer and were substantially similar to control trees.[3]

Grapes

Control grapes appeared quite healthy, with no apparent abnormalities, good-sized with green healthy looking leaves. Grapes treated with 2,4-D at one-third of the field rate showed a dramatic response: brown, desiccated leaves, and poor growth in general. Glean at one-third the field rate also produced a dramatic effect. The plants were quite stunted, and the top leaves were yellow or brown, or in some cases, missing.

At the lowest concentration of 2,4-D, grape plants looked reasonably healthy. The grapes had set, and the leaves showed good color. There was some indication that the apices were not quite normal, but the size was good.

In contrast, one-hundredth of the field rate of Glean produced stunted grape plants of poor color. These plants appear to have suffered more than those treated with 2,4-D or any other herbicides in this study.

Roses

Control roses appeared quite healthy, and were in bloom at the time that these slides were taken. Roses treated with 2,4-D at 1/100 field rate showed some variability, but had good size and color.

Roses treated with Glean at one-hundredth of the field rate showed significant effects. The younger portion of the plant presented pale or yellow leaves, and the plants were stunted. At higher concentrations, the response was much more dramatic.

While the effects of Glean at low levels appeared to be significant, the researchers at the Prosser Experiment station pointed out that the plants had by late summer grown out of that state to a substantial degree.[2] It appeared that while low levels of the sulfonylureas could have a dramatic effect on the appearance of plants, this did not necessarily mean that the health of the plants was seriously impaired.

Tour of Badger Canyon

After visiting the experiment station, Dr. Fletcher visited several farms in the Badger Canyon area, from Kiona, Northwest of the canyon, southwest to Finley at the far end of the canyon. In several instances he saw damage to crops that he feels could have been caused by herbicides. Some of these crop damage claims have been investigated by scientists from Washington State University, and the majority of the symptoms are attributed to something other than herbicides.

Badger Canyon is about twenty miles long, its long axis running east-west. It is bounded on the south by the Horse Heaven Hills, which gradually rise up several hundred feet from the canyon floor, giving more the appearance of a gently sloping valley than a canyon. North of Badger Canyon are a series of smaller hills or low ridges (Red Mountain, Badger Mountain, and others). The natural vegetation is sage and native grasses, and the average annual precipitation is low, usually 10 inches a year or less. Irrigated crops grown in the canyon include apples, plums, cherries, peaches, apricots, grapes, alfalfa, asparagus, and some ornamentals.

Dr. Fletcher visited an orchardist near Benton City who grew apricots, apples, and cherries. For both the apricots and cherries, fruit set had been very poor, and very little crop was realized in 1990. The grower in the attributes the poor fruit set to the effects of sulfonylurea herbicides, feeling that the early season application of these herbicides to the Horse Heaven Hills may have had an affect on the cherry or apricot trees' ability to set fruit. The investigation by Washington State University concluded that the damage was caused either by birds in one orchard and by frost in another.[2] The grower disputes this, citing the absence of birds at the time of the damage, and the absence of significant cold weather. He also cites the history of weather in the area and that this orchard has historically not been subject to frost damage.

Examination of the cherry trees showed forked apices, an indication that the apices had been killed and that the lateral buds had been released. Many cherry trees had no fruit set, and those with less fruit set tended to be closer to the Horse Heaven Hills. The apricot trees also showed forked apices. Only one apricot tree in this orchard could be found with fruit on it.

In the same farm there was an apple orchard that appeared to be damaged. Most trees in this orchard has one or more of the following symptoms: leaves not expanded, short internodes, deformed leaves, leaves absent, or abnormal growth pattern at the end of the branch.

Moving down Badger Canyon, an asparagus field was visited. The grower said that the field had showed dramatic signs of damage in the previous year, primarily curling, and that they had not come back this year in a proper fashion. The grower also reported that it had been a very weak field this year.

Dr. Fletcher then went to Finley to another orchard, where he observed young peach trees. Their growth did not appear normal. The internodes were extremely short, and the leaves malformed. The report of the Washington State University Pesticide Response Team concludes that "propagation techniques used in the blocks likely contributed to the poor growth observed.[2]"

Conclusion

Dr. Fletcher was careful to point out that the damage he observed could not be easily explained. He felt that it may have been caused by herbicides, but that there is no conclusive evidence to support this. Thorough investigation of some of the crop damage claims by Washington State University Faculty resulted in the conclusion that, while there were some symptoms that could not be explained, the most severe effects observed could be explained by frost damage or bird damage and or poor grafting techniques. They also reported some symptoms for which no plausible explanation is presented.[2] These conclusions are viewed with some skepticism by the affected growers, and in any case the data supporting these or any other conclusions about the source of the damage are less than compelling.

This report is presented as an example of the difficulties that may be encountered in trying to determine the cause of plant damage. Differentiating the symptoms that might be caused by herbicides from those symptoms that might be caused by natural stresses (virus, disease, frost, insect, nutrient deficiency, and perhaps others) will be a challenge for those who wish to monitor for the effects of herbicides in natural systems.

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2) Mink, G. I. and W. E. Howell. An Evaluation of Problems Alleged to be Caused by Herbicide Drift into Badger Canyon during April, 1990. June, 1990.

3) Al-Khatib, K. Personal communication, February, 1991

Questions for Karl Arne

Q. I've heard it said that in Benton County since they banned the use of 2,4-D, the farmer has to use mechanical tilling to control weeds, and that has led to a significant increase in wind erosion. I don't remember that they banned 2,4-D in Benton County.

Q. They can't apply it aerially.

A. Is it your point that there would be an increase in dust, and this may . . .?

Q. [difficult to follow, but discussion around the question of whether wheat fields ever were weedy and soil bound better than now.]

Q. Would you expect to see a gradient effect according to the proximity of the trees to the source?

A. Initially, you would expect that, but I'm skeptical now. I think it may move and then drop, or there might be other mechanisms in effect. I think drift is one of the most poorly understood things there is.

Q. A little bit different model than this, but In sampling aquatic systems for drifting insects in response to an adjacent carbaryl spray project, you'll see an immediate response of drifting insects, even when you are a mile away from the stream, and sometimes you will see the pesticide move up and over and then drop into a different wind pattern.

Bioresponse of Nontarget Organisms Resulting from the Use of Chloropicrin to Control Laminated Root Rot in a Northwest Conifer Forest:

Part 1. Installation of Study

by

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ABSTRACT

Laminated root rot is a major root disease problem in the West. Several fumigants have been found effective in reducing or completely eradicating the pathogen from infested stumps and roots. In 1989 EPA approved the use of chloropicrin as a stump treatment to control laminated root rot. Reports detailing chloropicrin concentration in the environment as a result of the treatment or the potential impacts of chloropicrin on nontarget forest organisms are lacking. A disease control study was established to further evaluate the effectiveness and cost of stump application of chloropicrin to control laminated root. The bioresponse study described here will take advantage of plots and treated stumps established for the disease control study by monitoring treated areas and quantifying the changes in four segments of the ecosystem likely to be sensitive to chloropicrin: vascular plant community, detrital foodweb, soil microarthropods, and mycorrhizae formation. Due to the anticipated slow release of chloropicrin from the stumps, monitoring will continue for 3 years. Only preliminary results are available now.

INTRODUCTION AND BACKGROUND

Laminated root rot

Laminated root rot is widespread throughout the range of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Douglas-fir is the most economically important host, but nearly all conifers seem to be susceptible to some degree. The disease reduces forest productivity annually by about 4.4 million m^3 (Childs and Shea 1967, Nelson et al. 1981).

When infected trees die, the pathogen continues to live saprophytically in infested butts and large roots for as long as 50 years (Childs 1963, Hansen 1976, 1979). Infection in a young stand begins when roots of young trees contact residual infested stumps and roots from the preceding stand. The infection spreads between living trees through root contacts (Wallis and Reynolds 1965). Immediate succession by Douglas-fir or other highly susceptible species on a site infested with *Phellinus weirii* often results in more disease and heavier losses in the new stand (Wallis and Reynolds 1965).

Fumigation for control of laminated root rot

Fumigation is one means of reducing inoculum of some root rotting fungi (Thies 1984). Reports of fumigant application to soil as well as directly to wood to destroy particular fungi have been reviewed previously (Filip 1976; Thies and Nelson 1982, 1987). In 1989 use of chloropicrin to reduce inoculum of laminated root rot in Douglas-fir stumps was approved by the Environmental Protection Agency. While silvicultural manipulations will remain the most widely used control for laminated root rot, fumigation will be an alternative tool available to the land manager.

DISEASE CONTROL STUDY

The disease control study was established to determine the cost and degree of reduction in the reappearance of laminated root rot in a replacement stand using chloropicrin as a stump treatment. Stumps were fumigated during October 1988, and the area was intervals of 2 years to record seedling growth and mortality.

Study Area

The study area is an 8-ha clearcut on a 2% south-facing slope on the Olympic Peninsula near Matlock, WA (latitude 47° 14' N.; Longitude 123° 25' W.); mean elevation is 175 m; mean annual precipitation is 125 cm; soil in the study area is a Hoodsport Gravelly Sandy Loam. The Hoodsport soil series formed in glacial deposits of 50 to 75 cm of loose ablation till overlaying very compact lodgement till. The site is class III (McArdle et al. 1961), and supported a 65-year-old naturally regenerated stand that was predominantly Douglas-fir (99% by harvest volume). Western hemlock (*Tsuga heterophylla* (Raf.)Sarg.) constituted the remainder of the overstory. The understory was primarily salal (*Gaultheria shallon* Pursh) with some sword fern (*Polystichum munitum* (Kaulf.) Presl) and a lesser component of twin flower (*Linnaea borealis* L).

Plots

The study area was subdivided, systematically searched, and the location of each *P. weirii* infested stump was mapped (Thies and Hoopes 1979). Using a map depicting the locations of infested stumps, circular, 0.04-ha, nonoverlapping treatment plots were established in the study area in locations to include concentrations of infested stumps. An inoculum index (INOC) was calculated for each infested stump, based on stump diameter and stump condition, and summed to get a total INOC for each plot. Based on total INOC, plots were stratified into 8 blocks of 4 plots each.

Treatments

Treatment involved application of chloropicrin at either 100% or 20% of the labeled dosage, and either all stumps were treated or only those with stain (or advanced decay) typical of *P. weirii* were treated. Three chloropicrin treatments and an untreated check were randomly assigned within each group of four plots in a block:

1. check (nothing done to the stumps);
2. 100%, all stumps;
3. 20%, all stumps;
4. 100%, stain only stumps. The label dosage is about 3.3 ml of chloropicrin per kilogram of stump and root biomass.

Application of fumigant

Treatment holes, 3.2 cm diameter, were drilled vertically into each stump top either at stained areas when present, or in unstained wood. Stumps with a diameter of 32.5 cm or less had a minimum of four treatment holes drilled, one in each quadrant of the stump top; larger stumps had at least eight treatment holes drilled with at least two in each quadrant of the stump top. To avoid drilling through the stump, holes extended only slightly below the soil line. A dose of chloropicrin was distributed equally to all holes in a stump. After fumigant application, each hole was plugged tightly with a hemlock dowel that was sealed to resist passage of the fumigant.

MEASURING BIORESPONSE TO CHLOROPICRIN IN A FOREST ECOSYSTEM

Ecological impacts of chloropicrin

Chloropicrin (trichloronitromethane) is a general biocide that has been used as a soil fumigant and studied for its effectiveness in reducing specific pests; however, examination of the literature does not provide a basis for predicting the effects of chloropicrin applied to stumps on nontarget organisms. The effect could be beneficial as in agricultural fields where pathogens are reduced or negative such as the observed reduction in vesicular-arbuscular mycorrhizae in crop soils (McGraw and Hendrix 1986).

Chloropicrin has documented effects on bacteria, fungi, nematodes, and higher plants. To our knowledge, there is no published information on the effects of chloropicrin on protozoa, lichens, N-fixing bacteria, or moss, but these organisms are important in nutrient cycling in forests and should be investigated. Castro et al. (1983) found that four species of *Pseudomonas* were capable of degrading chloropicrin by successive dehalogenation to nitromethane. Other reports indicate, however, that chloropicrin is toxic to soil bacteria (Martin and Kemp 1986; Ono 1985).

The maximum distance chloropicrin diffuses in a root system or the rate at which it leaves the root system is not known. Two growing seasons after treatment the odor of chloropicrin was commonly detected when roots were cut 1 m or less from the treated stump, and occasionally detected when roots were cut as far as 2.4 m from the stump (Thies and Nelson 1987). Increasing moisture levels (20% of field intervals of 2 years to record seedling growth and mortality.

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The maximum distance chloropicrin diffuses in a root system or the rate at which it leaves the root system is not known. Two growing seasons after treatment the odor of chloropicrin was commonly detected when roots were cut 1 m or less from the treated stump, and occasionally detected when roots were cut as far as 2.4 m from the stump (Thies and Nelson 1987). Increasing moisture levels (20% of field capacity and above) and decreasing temperature reduce volatilization rates of chloropicrin (Tanagawa et al. 1985). Thus we anticipate that disappearance of chloropicrin from a treated site in the Pacific Northwest may take several years.

Objectives

To determine the changes in population or diversity of specific nontarget components of a coastal ecosystem that occur as a direct result of the application of chloropicrin to stumps on an infested site to control laminated root rot.

This research will provide data to evaluate the impact of applying chloropicrin to stumps on four essential and potentially sensitive segments of the forest ecosystem: vascular plant community, detrital foodweb, soil arthropods, and the formation of mycorrhizal roots on Douglas-fir seedlings. Additionally, this research will establish the field persistence of concentrations of chloropicrin adequate to have an impact on higher plants. This research will form a basis for developing future pest management strategies involving the use of chloropicrin in forestry.

Research approach

Five separate evaluations are being conducted simultaneously by various research teams, each collecting samples from the same plots. Stumps on the study area were fumigated in fall 1988 as part of the disease control study described above. Sampling for bioresponses began in spring 1989 and will continue through fall 1991; analysis and publication should be completed by the end of 1992. In general, each team will evaluate the impact of the existing chloropicrin treatments on a class of indicator organisms on an area (plot) basis. In some instances, we will also look at the worst case situation and examine the impact immediately adjacent to treated stumps. We are prepared to shift our sampling emphasis if early results indicate that more or less intensive sampling is appropriate. We are also prepared to continue the evaluation for additional years if analysis of the data after the third sampling season suggests that it would be worthwhile and if additional funding can be obtained.

The disease control study involved four treatments, three chloropicrin treatments and an untreated check, randomly assigned to four plots within each replicate. These treatments were applied to eight replicate groups of plots. Replicate blocking was based on the inoculum found on each plot. Due to limitations of resources, the bioresponse evaluations are being conducted on five replicates of three treatments:

1. check (nothing done to the stumps);
2. 100% labeled dosage, all stumps treated;
3. 20% labeled dosage, all stumps treated.

In general, the statistical analysis will be an analysis of variance of a randomized complete block design with three treatments and five replicates. We anticipate making two orthogonal contrasts: check vs. all treatments and 100% labeled dosage vs. 20% labeled dosage. Additional analyses will be made of appropriate data to examine shifts in populations and species richness over time.

The following five evaluations are being conducted:

1. field persistence of chloropicrin;
2. impacts on naturally occurring higher plants;
3. impacts on the detrital foodweb;
4. impacts on the soil arthropods; and
5. Impacts on mycorrhiza formation.

COOPERATION

The following organizations are cooperating in support of this study: Simpson Timber Co.; Great Lakes Chemical Co.; National Agricultural Pesticide Impact Assessment Program (NAPIAP), U S Department of Agriculture; Pacific Northwest Research Station, U S Department of Agriculture, Forest Service; and the departments of Forest Science, Botany and Plant Pathology, and Entomology, Oregon State University.

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Bioresponse of Nontarget Organisms Resulting from the Use of Chloropicrin To Control Laminated Root Rot in a Northwest Conifer Forest:

Part 2. Evaluation of Bioresponses

by

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Known impacts of chloropicrin

Most research has concentrated on the effects of combinations of methyl bromide and chloropicrin fumigants on disease-causing organisms. Little research has been reported on the response of saprophytic fungi to chloropicrin. Some evidence exists for the escape of some species of fungi during fumigation efforts thus positioning the survivors for rapid recolonization of the available substrate. The occurrence of *Trichoderma* spp. in roots of fumigated Douglas-fir stumps was noted during the evaluation of several fumigants for the control of laminated root rot (Thies and Nelson 1982). Following fumigation, increased numbers of *Trichoderma* spp. were found in some soils (Mughogho 1968). Combinations of methyl bromide and chloropicrin control a variety of soil-borne diseases in forest tree nurseries (Peterson and Smith 1975) and can reduce populations of various other fungi. These include VA mycorrhizal fungi (Jones and Hendrix 1987, McGraw and Hendrix 1986), ectomycorrhizal fungi (Trappe et al. 1984), as well as root disease-causing species of *Pythium, Rhizoctonia, Phoma* (Sumner et. al. 1985), *Helicobasidum momta*, (Sakuwa et al. 1984), *Verticillium albo-atrum*, and *Sclerotium* (Himelrick 1986).

Nematode populations are reduced by chloropicrin alone and in combination with methyl bromide or dazomet. Research has concentrated on the commercially important parasites of plant roots and no information was found on free-living fungal or bacterial feeding nematodes. Fumigation reduced the nematode root pathogens *Meloidogyne* spp. and *Paratrichodorus minor* (Sumner et al. 1985) and chloropicrin in combination with ethylene dibromide reduced *Belonolimus longicaudatus, Meloidogyne incognita*, and *Hoplolaimus galeatus* (Rhoades 1983).

As a measure of species richness, soil arthropods in conifer forests of the Pacific Northwest average nearly 200 species/m^2 (personal communications Andrew R. Moldenke, Oregon State University, Corvallis, OR). Thus soil arthropods may be an important and sensitive indicator to evaluate potential ecosystem effects of chloropicrin on nontarget soil organisms. Soil arthropods are sensitive indicators for soil moisture, successional stages, plant communities, and mycorrhizal biomass (Cromack et al. 1988, Moldenke and Fichter 1988). All arthropod species are presumed to be sensitive to chloropicrin, although differing feeding preference, microhabitat choices, and position in the food web will expose the diversity of species to different concentrations of fumigant.

Objectives

One objective of this study was to determine changes in diversity of specific nontarget organism components of a coastal ecosystem which occur as a result of application of chloropicrin to stumps to control laminated root rot. A major challenge was to evaluate the impact of chloropicrin on a range of organism groups. A sample scheme capable of distinguishing at least two levels of spatial variability was designed. Background variability of the organisms resulting from heterogeneity in soil microsites and seasonal shifts is a common difficulty in studies of soil organisms. Sampling intensity had to be great enough that treatment effects could be assessed, without increasing the work load beyond that of a limited budget.

The approach described here can be applied to any ecosystem, and to a number of situations where effects of pesticide application need to be assessed. With this approach, the effect of pesticide on plants, soil detrital foodweb organisms, mycorrhizal colonization of dominant plants, and survival of sensitive bioassay plants can be interpreted in a biologically meaningful manner at a number of spatial scales. For example, the pesticide may reduce root rot, but destroy those organisms responsible for nutrient cycling, or could allow another pathogen to become a problem, exchanging one pathogen problem for another. Root-feeding nematodes might be advantaged, resulting in seedling death. Alternatively, greater mycorrhizal colonization of roots might occur, and benefit the survival of desired plant species. Before we continue with the use of pesticides, we should attempt to understand beneficial or detrimental interactions which may be produced. Our approach allows us to assess these possible beneficial or detrimental effects.

Experimental site

When the experimental site was cut early in the fall of 1988, see Part 1. of this study, p. 81) soil consisted of a moss (bryophyte) layer overlying poorly developed litter, and fermentation layers, with a 1-5 cm depth humus soil horizon resulting from the rapid decomposition rates in these systems. When soil development is limited, nutrient cycling is usually tightly coupled to organism dynamics (Read and Birch, 1988; Perry *et al*. 1989). When litter falls to the forest floor, it is rapidly decomposed, and the nutrients converted to microbial biomass. These nutrients are then released by arthropod, nematode and protozoan grazing of decomposers, resulting in high soil fertility and maximum nutrient availability to plants during times of rapid plant utilization (Coleman 1985). However, with clearcutting, much of the thin soil layer was destroyed and mineral soil revealed.

The location of each infected stump in the clearcut stand and three mature trees in adjacent uncut stands were mapped. Circular treatment plots 0.4 ha in size were established in the clearcut area and blocked into groups of four based on similar inoculum rating (see part 1 for explanation). Each of the four plots in each block received one of the following treatments: all stumps treated with 100% chloropicrin, only infected stumps treated with 100% chloropicrin, all stumps treated with 20% chloropicrin, and a control plot with no application chloropicrin. The 100% label dosage was 3.3 ml of chloropicrin per kilogram of stump and root biomass.

Choice of bio-response parameters

Bio-response assessment was initiated in the spring of 1989. Five major component groups of organisms were assessed; the above ground plant community, detrital foodweb organisms, mycorrhizal colonization of Douglas-fir roots, and the response of chloropicrin-sensitive plants. These assessments will continue until the fall of 1991.

Soil foodweb organisms respond more rapidly than plants to environmental change and disturbance. Responses of bacteria and fungi often reflect day-by-day fluctuations in temperature, moisture, grazing, and nutrient availability, and thus are not useful as measures of ecosystem response to disturbance. However, by examining changes in activity, in ratios of fungal to bacterial biomass, or important populations of microorganisms, longer term impacts on the system can be assessed.

Protozoa, nematodes and microarthropods are intimately involved in nutrient cycling (Coleman 1985) and thus are good indicators of ecosystem health (Ingham et al. 1985; Ingham and Horton, 1987). Mycorrhizal fungi are extremely important in survival of Douglas-fir; in field sites, Douglas-fir is not found without the symbiotic fungus (Trappe et al. 1984). Thus, monitoring mycorrhizal fungi can be extremely important in determining if pesticides have an effect.

Tomatoes and alfalfa were planted in the field sites. Tomato is extremely sensitive to chloropicrin (Rhoades 1983), and alfalfa is symbiotic with N-fixing rhizobium. Release of chloropicrin in field soils could be monitored with tomato, and natural populations of rhizobia could be assessed by examining the roots of the alfalfa.

Spatial scales

Within the 0.4 ha circular plots, responses were monitored on several spatial scales, as well as over time.

Aboveground higher plant responses were assessed each spring and fall by monitoring percent cover of each species present,

(1) in the entire plot,

(2) in six 2 m X 3 m plots arranged sequentially at 1, 2 and 3 meters from four individual stumps at the edge of the plot, and

(3) in six 1 meter square plots located between two stumps within 2 meters of each other.

Detrital foodweb responses (numbers and activity of bacteria, active and total fungal biomass, and numbers and community structure of protozoa, nematodes, and microarthropods) were monitored over time. Samples were taken mid-spring, early summer, late summer, and mid-fall each year.

To determine if soil organism numbers, activity or community structure changed on a whole plot spatial scale, twelve random points were sampled in each of five plots per treatment on the four sample dates each year. The same four random sets of coordinates were designated in each third of the plot to maximize coverage of the area.

To determine if a localized effect of chloropicrin treatment occurred, soil samples were taken at 4 distances (0.5, 1.0, 1.5, and 2.0 m) along three equally spaced radii extending from tree stumps (five separate tree stumps per treatment). While soil samples for microarthropods were taken from each point, samples for the other organisms were bulked by distance. Since it was chloropicrin treatment, not soil heterogeneity, that was being assessed, averaging the differences resulting from soil microsite heterogeneity was acceptable.

On each sample day, the actual point from which soil was removed was repositioned from the original marker by pre-determined distances. A 7.5 cm diameter, 7.5 cm deep sample of soil was removed from each point for microarthropod estimates. An approximately 2 cm diameter, 5 cm deep soil sample was taken from each point, but soils from each of the three quadrants (i.e., 4 soil samples) were bulked for bacteria, fungi, nematodes, and protozoa assessments.

Active bacteria, active fungi, and total fungal biomass were assessed by the FDA method of Ingham and Klein (1984). Total bacterial numbers were assessed by FITC staining (Babiuk and Paul, 1970). Protozoa were determined by MPN and direct microscopic viewing (Darbyshire, et al. 1974). Nematodes were assessed by Baerman extraction and microscopic observation (Anderson and Coleman, 1977). Microarthropod numbers were assessed by high efficiency Tullgren extraction and observation (Merchant and Crossley 1970).

Chloropicrin-sensitive bioassay plants (tomatoes and alfalfa) were planted each year in the spring at 1 and 2 meters distance from stumps of five trees of each treatment type and were randomly placed in another five plots of each treatment. Survival was assessed on each sample date. In the second year, a ring of alfalfa was planted at 1 meter distance from each stump. All alfalfa plants were examined for N-fixing bacteria nodules on their roots at the end of the second year.

RESULTS

Chloropicrin application was not the only environmental variable to which these sites were responding. Two extremely important correlated variables were (1) removal of canopy cover and (2) compaction of the soil by heavy machinery. All the experimental sites were exposed to both, either of which may have ecosystem effects equal to or greater than the chloropicrin treatments. The three types of plant plots, the two types of detrital foodweb organism plots, placement of chloropicrin-senstitive plants, and placement of Douglas-fir seedlings to assess mycorrhizal colonization allowed assessment of bio-responses to these environmental variables.

In addition to compaction and canopy removal, we observed a gradient of organism numbers and community structure from north to south and east to west in this stand. The blocking initiated at the beginning of the study based on *Phellinus* inoculum density in stumps reflected changes in soil organism community structure, and was related to surface soil characteristics. We use these block effects as covariates in statistical analyses.

Pesticide application did not impact establishment, growth or survival of any plant species in the first year after application of chloropicrin.

In the first year, chloropicrin impacted soil bacteria, fungi, protozoa, and nematodes only in a few isolated points near stumps:

(1) area 8, point 2, 20% chloropicrin treatment,

(2) plot 2, 20% treatment, 2.0 distance,
(3) plot 602, 100% treatment, 2.0 distance, and

(4) plot 736, 100% treatment, 2.0 distance.

When these single points were averaged with all five replicates from a treatment, variance was significantly increased, but no significant treatment effect was observed.

In these isolated cases, reductions in numbers of organisms were considerable, from around 10^7, or 10 million total number of bacteria per gram soil to less than 100,000 per gram soil in impacted points. Fungi normally measured about 600 m of hyphae per g with between 10 and 50% of those hyphae active, dependent on season. In impacted areas, less than 5 m of hyphae per g were found, with no active hyphae present. Protozoa tended to number around 10,000 per g soil, but in impacted soils, were less than 10 per g. We have not finished assessing protozoan community structure, but no immediately obvious changes were detected in the first year. In control soils, nematodes tended to number around 100 per 5 g soil, but in impacted soil, less than 10 per 5 g soil were found. However, no significant changes in nematode community structure were observed in the first year.

Microarthropod community structure has been assessed for the first year, and it is clear that though individual species respond both positively and negatively to a chloropicrin-fumigated environment, these responses were not of great enough magnitude to radically alter total densities or biomass either around individual trees, or in whole plots. However, in tree-centered samples, guild diversity was decreased in the 20% treatments, and comparisons of individual species showed that 15 of the commonest species decreased with increasing dosage, 8 increased with dosage, 2 were highest in 20%, and 3 were lowest in 20% chloropicrin treatments. The commonest species of springtail was unaffected by chloropicrin, whereas most oribatid species were affected, although increases and decreases tended to cancel out overall effects. Coupling these analyses with covariate information (removal of canopy cover, compaction, plant diversity, etc.), should lead to identification of a small set of indicator taxa that can be used for more efficient monitoring of similar situations.

In the second year, the areas impacted in the first year expanded, and four to five new points of impact were observed. The position of newly impacted points appear random. Complete analysis of variance has not been performed at this time, because not all samples have been completely analysed.

There was no difference between survival of tomato plants in year one in any treatment, but in year two, more tomato plants died in the 100% treatments than in other treatments. There was no significant difference in nodulation of alfalfa roots in any plot in any year.

CONCLUSIONS

In the first year after chloropicrin application, reductions in organism numbers in a few isolated points and changes in individual species of microarthropods were significant on the spatial scale of a single stump. These impacts could be important to a new seedling trying to obtain nutrients from the soil in an impacted area. On an larger spatial scale, such as the 0.4 ha plots, and certainly on an ecosystem-level, the impact was not significant, based on plant response (no impact on plant community structure or on chloropicrin-sensitive bioassay plants) or on numbers of bacteria, fungi, protozoa, nematodes or microarthropods.

Will the impact be detrimental or beneficial, in the long term? In the second year, numbers of plant-feeding nematodes have increased from barely detectable numbers present in soil to comprising up to 50% of the nematode population in some samples in the second year. This could be detrimental to Douglas-fir seedlings, but this is a stand-wide effect, not an effect of chloropicrin application. In fact, those points impacted by the chloropicrin have below-detection level numbers of nematodes, and so, chloropicrin application could be beneficial for Douglas-fir seedlings growing in those areas, because the plant-feeding nematodes have been negatively impacted in those places.

The increase in plant-feeding nematodes has coincided with increase in exotic weed species on these sites. Plant-feeding nematodes may be attacking the roots of these weedy species and thus be reducing competition between the weed species and Douglas-fir seedlings. In areas impacted by chloropicrin, it may be that the weeds don't suffer limitation by root-destroying nematodes and the Douglas-fir seedlings will experience increased competition. We will be able to assess this interaction by continued examination of the soil and the plant communities over time.

All of our information supports the conclusion that very little chloropicrin escaped from roots in the first year. Only at a few points, not significant on an ecosystem scale, were effects detected. In the second year, responses of soil organisms and chloropicrin-sensitive plants provided information that more chloropicrin escaped from roots, but still not enough to result in an effect on the plant community. Early warning that potential effects may occur is being provided by the soil organisms, but we don't have the database to tell us if this means an overall detrimental effect on the ecosystem, or an overall beneficial effect on the ecosystem.

We know that the fungus that causes laminated root rot is being killed in these stumps (Thies and Nelson, 1985). Within the stump, other organisms are being killed, and it is likely that wood decomposition is being slowed. Is that positive or negative? We don't know. What is the balance sheet going to indicate in ten years? Will the detrimental effects outweigh the positive?

Whatever happens in this particular ecosystem, however, the type of sampling being done, limited as it is, allows biologically meaningful conclusions to be made about the impact of this pesticide in this ecosystem. This approach of assessing bio-responses gives us the ability to make predictions about the possible trajectories this ecosystem may take. We have the means to make useful predictions, and by looking at this suite of organism responses, we can indicate problem areas before a situation may result in irreversible loss of a particular habitat or species.

So, is chloropicrin use detrimental? If the points where organism numbers have been negatively impacted don't spread farther than they have in the second year, and if the pathogens don't cause a problem as impacted areas are re-colonized, the liklihood is that the pesticide should continue to be registered for this use, with the clear explanation that higher doses, applied in a different manner, might be detrimental. However, impacted areas are likely to continue to expand, because not all the pesticide has volatilized from the stumps. How far will the affected areas expand? Will pathogens colonize the center of these impacted areas and cause problems? Will we select for worse disease problems by using this pesticide? Once all the chloropicrin is out of the stumps, how long before affected areas will be re-colonized by the normal organisms? Or will these areas be pushed into completely different ecosystem trajectories, similar to what has occurred in some plots in southern Oregon with completely different disturbances (Borchers and Perry, 1989)? Answers to these questions are not available. But continued monitoring in this system will allow these questions to be answered for this system. Extrapolations can be made to other systems with the understanding that differences between another system and this one must be understood in predicting possible impacts.

COOPERATION

The following organizations are cooperating in support of this study: Simpson Timber Co.; Great Lakes Chemical Co.; National Agricultural Pesticide Impact Assessment Program (NAPIAP), US Department of Agriculture; Pacific Northwest Research Station, US Department of Agriculture, Forest Service; and the departments of Forest Science, Botany and Plant Pathology, and Entomology, Oregon State University.

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Birds and Pesticides

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ABSTRACT

Die-offs or population declines of terrestrial birds caused by pesticide use are highly visible and frequently generate intense public concern. Unfortunately, birds generally are more sensitive to organochlorine, organophosphorus, or carbamate insecticides than are mammals. Organochlorine compounds cause reproductive impairment at relatively low concentrations by interfering with the proper functioning of the shell-gland, thereby causing eggs to be formed with extremely thin shells. Organophosphorus and carbamate insecticides are more toxic to birds than mammals due to deficiencies in liver enzyme systems. Therefore, the USEPA requires data on bird exposures and sensitivities as part of the registration process for agricultural chemicals and uses reports of bird kills following pesticide applications as evidence of unacceptable risk to justify alterations in approved use scenarios.

The Wildlife Ecology Team at the USEPA Corvallis Environmental Research Laboratory has been evaluating the methods used for terrestrial ecological risk assessment, including refinements of laboratory techniques for measuring directs toxicity and reproductive effects, studies of how avoidance and aversion behaviors affect the outcome of toxicity tests, relative contribution of the various possible exposure routes, and extrapolation of laboratory results to the field. Another objective of the Team is the development of biomarkers of exposure and hazard for terrestrial wildlife species. Through the use of appropriate cellular or biochemical measures, detrimental impacts of pollutants on free-ranging wildlife can be detected before large-scale die-offs or irreversible population declines occur. Biomarkers have been developed for several species of waterfowl, gallinaceous birds, and shorebirds for measuring tissue and serum enzyme changes (esp. cholinesterase), immune dysfunction, morphometric aberrations, and eggshell quality. Ecotoxicology and population studies have included observations of pesticide effects on nesting behaviors of songbirds, waterfowl and upland game birds. Modelling of population consequences of pesticide exposure to representative passerine species is underway. Selected examples of studies conducted in each of these research areas will be presented to illustrate the state of knowledge in pesticide risk assessment for birds, some promising new biomonitoring methods, and where critical data gaps still exist.

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Effects of Pesticides on Upland Game:

a Review of Herbicides and Organophosphate and Carbamate Insecticides

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ABSTRACT

The adverse impacts of environmental contaminants on natural resources have long been recognized and various pesticides have been implicated in wildlife die-offs and population declines. However, little is known regarding the effects of agri-chemicals on upland game. Research in Great Britain has addressed the long-term effects of pesticides on the gray partridge (Perdix perdix), *providing evidence that pesticide (both herbicides and insecticides) use has resulted in partridge declines. Little direct partridge mortality resulted from pesticide use. Instead, pesticides increased chick deaths by reducing their food supply (i.e. insects and forbs).*

In southern Idaho, as well as in many other areas of the west, farmers use pesticides on a wide variety of crops, and these pesticides are vastly different in their toxicities to wildlife. In Idaho, four pesticides have been implicated in wildlife die-offs. Farmers reported sage grouse (Centrocercus urophasianus) *dying in their fields in the late 1970's and early 1980's in southeastern Idaho. In agricultural areas, sage grouse feed on insects and forbs, and they may be exposed to pesticides several times during the summer. Sage grouse ($N = 73$) were equipped with radio transmitters as they arrived on summer range in 1985 and 1986. About 90 percent of these grouse used farmlands, 20 percent were actually exposed to pesticides and about 15 percent died as a result of the exposure. Moreover, all of the detected deaths involved juveniles that died in alfalfa or potato fields. Thirty birds found sick in alfalfa fields sprayed with dimethoate were also equipped with radio transmitters. Twenty of these birds eventually died, including five adults.*

Substantial evidence suggests that partridge populations are declining from pesticide use. Moreover, sage grouse, which spend only a small part of their life in agricultural areas, are dying as a result of pesticide exposure. Given this information, it seems reasonable to suspect that the pheasant (Phasianus colchicus), *a species strongly tied to farmland, is also being affected by pesticide use. Unfortunately, data are not currently available to support or reject this notion.*

INTRODUCTION

The adverse impacts of environmental contaminants on natural resources have long been recognized and various pesticides have been implicated in wildlife die-offs and population declines (Henny et al. 1977, Hudson et al. 1984, Potts 1986, Smith 1987). Much of this research has focused on the effects of organophosphate and carbamate insecticides on wildlife, especially waterfowl and to a lesser extent, gallinaceous species.

A number of reports are available that detail wildlife losses following the application of various pesticides (Zinkl et al. 1978, 1981, Hill and Mendenhall 1980, White et al. 1982, Seabloom et al. 1973, Henny et al. 1985, and others). Moreover, the effects of herbicide treatment of sagebrush on sage grouse have also been well documented (Wallestad 1975a, 1975b, Braun et al. 1977). Unfortunately, there have been few field experiments addressing the effects of agri-chemicals, especially organophosphate and carbamate compounds, on upland game (Potts 1986, Blus et al. 1989, Rands 1985). The purpose of this paper is to review current knowledge of the effects of herbicides and organophosphate and carbamate insecticides on upland game based on field studies, identify potential problems and suggest topics for future research.

Pesticides - Types and Toxicities

More than 160 million acre-treatments of organophosphorus and carbamate pesticides are estimated to be applied to farmland and forests each year (Smith 1987). Throughout the United States, Smith (1987) reports that 108 different organophosphorous and carbamate pesticides are used. Many of these agri-chemicals are used in Idaho (Table 1) and are commonly applied to crops used by pheasants, gray partridge, sage grouse and other upland species.

Of the 16 insecticides most frequently applied to Idaho farmland, 10 (63%) have LD_{50}'s (acute oral dose), $<= 20$ mg/kg (Table 1). Moreover, 4 (25%) of these compounds have been implicated in wildlife die-offs (Blus in press, Blus et al. 1989). Although the toxicities of most of these compounds to pheasants and other upland species have been established under controlled laboratory conditions, few attempts have been made to relate these data to field situations (Smith 1987). For instance, dimethoate is one of the most commonly used insecticides in the western United States and has been available for a number of years. The LD_{50} for dimethoate is 20 mg/kg (Hudson et al. 1984) for pheasants, suggesting that it is relatively toxic to upland game. At least 9 other pesticides used in Idaho have lower LD_{50}'s (i.e. are more toxic) than dimethoate. However, it is the only compound (except methamidophos) that has been implicated in > 1 die-off of upland species in Idaho and this was not reported until 1989 (Blus et al. 1989). The LD_{50}'s for the other, more toxic, compounds suggest that they too may pose a problem for free-ranging wildlife. Whether or not these problems occur is unknown and the relationship of laboratory generated LD_{50}'s to field situations remains unclear.

Wildlife Mortality

Mortality of upland game exposed to pesticides may occur either directly or indirectly as a result of this exposure. Direct mortality occurs when the bird becomes functionally intoxicated and cholinesterase depression is too high for the animal to recover. Indirect mortality may occur when a pesticide predisposes birds to higher rates of predation or other forms of mortality; it may also occur when pesticide applications reduce a bird's food supply to the point where starvation occurs. Both types of mortality have been well documented for several species of upland game.

Indirect Effects

Potts (1986) provided evidence that both herbicides and insecticides caused relatively high indirect mortality in gray partridge. In one of the few long-term studies addressing the impacts of agri-chemicals on upland game, Potts (1986) demonstrated that the use of pesticides reduced the food supply for partridge chicks, ultimately resulting in high starvation rates. This research showed that herbicides reduced the amount of broad-leafed forbs used for food by partridge. The reduction of forbs eliminated habitat for insects, resulting in fewer insects and a simpler plant/animal community. Additional use of insecticides further decreased the number of insects. The end result was a greatly reduced food supply for partridge (Potts 1986, Rands 1985).

Table 1. Organophosphorus and carbamate pesticides used in southern Idaho and their acute toxicities to pheasants[a].

Pesticide	Use	Acute Oral LD_{50} [mg/kg]
Aldicarb	Potatoes	5.3 (3.0-7.4)[b]
Carbofuran	Alfalfa	4.2 (2.4-7.2)
Chlorpyrifos	Alfalfa	8.4 (2.8-25.5)
Diazinon	Field crops	4.3 (3.0-6.2)
Dimethoate	Alfalfa, Wheat	20.0 (15.9-25.2)
Disulfoton	Alfalfa, Potatoes, Wheat	11.9 (8.6-16.5)
Malathion	Field crops	167.0 (120-231)
Methamidophos	Potatoes	Unknown
Methidathion	Alfalfa	33.2 (17.3-63.5)
Methylparathion	Alfalfa, Peas	8.2 (5.7-11.9)
Mevinphos	Potatoes	1.4 (0.95-2.0)
Naled	Alfalfa	120.0 (30.0-480)
Oxydemeton Methyl	Potatoes	42.4 (30.6-58.8)
Parathion	Potatoes, Grain	12.4 (10.1-15.2)
Phorate	Alfalfa, Potatoes&2 Sugarbeets	7.1 (4.9-10.3)
Trichlorfon	Alfalfa, Sugarbeets	95.9 (76.1-121)

[a] Data from Hudson et al. (1984)

[b] 95% confidence intervals in parenthesis.

Hill and Robertson (1988) suggest that pesticides have the same adverse effects on pheasant populations as they do on partridge populations. However, Hill and Robertson's data on pesticides and pheasants are much more limited than Pott's (1986) data on pesticides and partridge. Messick et al. (1974) also studied the effects of pesticides on pheasants in Idaho. These investigations reported lowered insect populations in the treated area and that juvenile pheasants consumed fewer insects in the treated area compared to an untreated area. Unfortunately, the relationship between food availability and juvenile survival was not discussed (Messick et al. 1974).

Pesticides may indirectly affect upland game populations by reducing food supplies. A second form of indirect effect may occur when sublethal exposures (i.e. intoxication) alter normal behaviors and/or decrease awareness, thereby increasing the risk of predation (Galindo et al. 1985) or other types of mortality (e.g. exposure, farm machinery).

Direct Effects

Messick et al. (1974) and Potts (1986) reported that direct mortality of game birds as a result of pesticide exposure was relatively rare and of little concern. This conclusion is not shared by other researchers and Blus et al. (1989) demonstrated that 2 commonly used insecticides frequently cause direct mortality to sage grouse in southeastern Idaho.

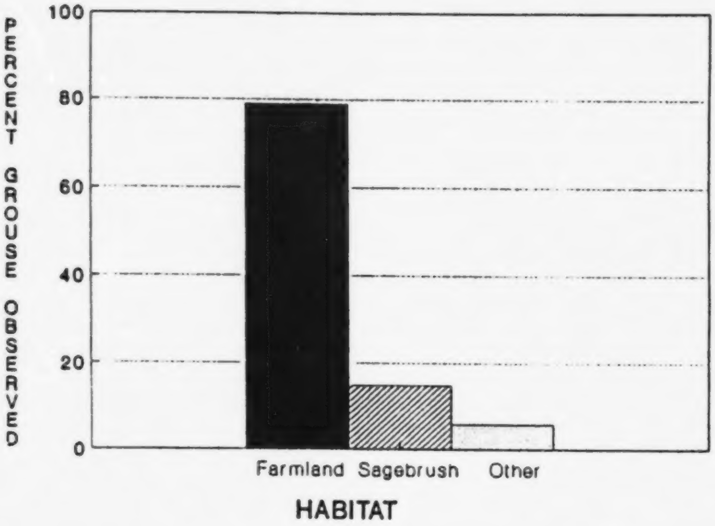

Figure 1. Habitat use by sage grouse during summers in southeastern Idaho.

Most sage grouse in southeastern Idaho are migratory and will move long distances between winter/breeding and summer range (Connelly et al. 1988). Although this species generally behaves differently than other upland species in terms of their fall-to-spring feeding habits and movements, sage grouse are similar to other game birds in their use of summer range. Like other species of upland game, sage grouse feed on forbs and insects during the summer and will move from relatively dry sagebrush uplands to agricultural areas to obtain these resources (Connelly et al. 1988, Gates 1983) (Fig. 1). While in agricultural areas, sage grouse may be exposed to pesticides (Blus et al. 1989).

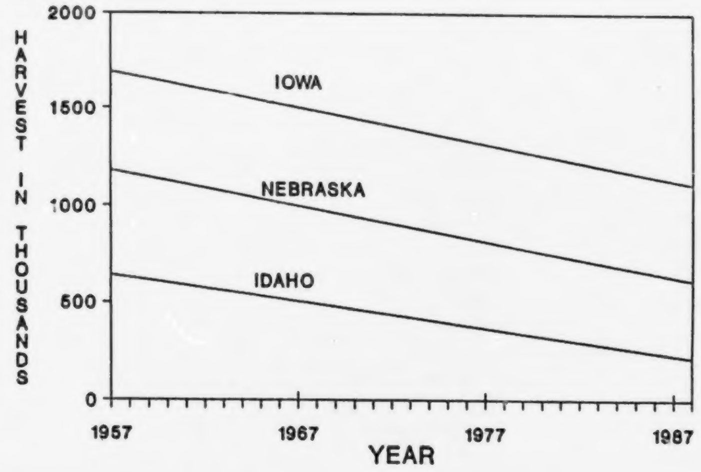

Figure 2. Pheasant population trends as reflected by harvest in three states, 1957-88.

Table 2. Mortality of sage grouse related to organophosphate pesticide use in southeastern Idaho, 1986[a].

	CONDITION[b]			
	Healthy		Intoxicated	
Age	N[c]	Mortality (%)	N[c]	Mortality (%)
Adult	15	0	5	100
Juvenile	28	25	25	56
Total	43	16	30	63

[a] Modified from Blus et al. (1989).

[b] Condition when captured; birds were classified as either healthy (no apparent exposure to pesticides) or intoxicated.

[c] Number of birds captured.

Blus et al. (1989) equipped sage grouse with radio-transmitters (N-43) as they arrived on summer range in 1985 and 1986. About 90 percent of these grouse used farmlands, 20 percent were exposed to pesticides and 15 percent died as a result of the exposure (Table 2). All of the detected deaths involved juveniles that died in alfalfa or potato fields. Thirty birds found sick in alfalfa fields sprayed with dimethoate were also equipped with radio transmitters. Twenty (67%) of these birds eventually died, including 5 adults. A die-off in one alfalfa field in 1986 involved 70 grouse.

CONCLUSIONS AND RESEARCH NEEDS

Substantial evidence exists to suggest that partridge populations are declining from pesticide use. Moreover, sage grouse, which spend only a small part of their life in agricultural areas, are dying as a result of pesticide exposure. Given this information, it seems reasonable to suspect that the farmland, is also being affected pheasant, a species strongly tied to by pesticide use. Pheasants are similar to partridge (Potts 1986) in that they have declined over a large portion of their range (Fig. 2). This decline is usually attributed to "farming practices" or changing habitats. Pesticides are a farming practice that can have a considerable effect on upland game habitat (Potts 1986). Unfortunately, pesticide use has seldom been identified as a factor of sufficient importance to pheasant populations to warrant intensive investigation (Messick et al. 1974). As an example, a symposium on pheasants and agricultural lands was recently published (Hallet et al. 1988). This symposium, contained 17 papers addressing a wide variety of topics, but none were concerned with the effects of pesticides on pheasants.

The information available on pesticides and upland game, together with data on pheasant population trends and farming practices, suggest that the relationship between pesticides and pheasants should be thoroughly investigated. If pesticide use is a concern, insect populations in brood rearing habitats can be evaluated. Long term pheasant trends in these areas should also be quantified and survival of juveniles to the fall should be examined. Potts (1986) suggested a technique for mitigating pesticide related mortality but this technique has not been experimentally evaluated in North America.

There also appears to be some argument over the relative importance of pesticide-caused direct mortality. A longer term study of the influence of this mortality on sage grouse populations would allow us to better understand this phenomenon as well as model the impact of pesticides on wildlife in agricultural systems.

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Questions for Jack Connelly

Q. To your knowledge has anyone been looking at some of the predators that some of those birds might have been ingested by?

A. There is some anecdotal information that OP's can have secondary effects, e. g. magpie dies of OP poisoning, dog eats magpie and dies too. But they have not been documented in experiments. In terms of decreases in predator populations that accompany decreases in upland game bird populations, I'd say no, it might be the other way around.

Q. I noticed that Pheasants Forever has claimed that a lot of habitat has been lost, and they attribute loss of pheasant populations to habitat loss as part of agricultural practices. [editor's note: not sure whether Pheasants Forever makes the claims, or merely reports what other said]

A. Well, habitat loss and agricultural practices go hand in glove. Habitat destruction, such as draining and plowing up a cattail slough, that's very visual, but you can't see a pesticide, though you may see the airplane briefly. So Pheasants Forever are very concerned about this other aspect.

(end of tape)

Q. Is there any evidence that birds are eating insects that have been hit with pesticides and re carrying a load, or whether insects that have been hit with pesticide and are staggering around with it on them are being picked up by the chicks?

A. As to staggering insects, yes, I think they do become prey to chicks, but as to insects being accumulators, I don't know.

Q. To follow up on that, when studying red-tailed hawks, we've seen hawks brought in with small passerines in their crops. Now redtails hawks are not passerine predators, so they are scavenging in this case.

A. Right. Larry is starting some pheasant research in northern California.

A. Larry Blus: Yes, two things on the sage grouse study.

1. [unintelligible]

2. This is the only study in which dimethoate has been shown to have an effect on vertebrates. It is not projected to be a problem in the environment.

The pheasants of Tule Lake: in potatoes sprayed primarily with methamidophos, birds collected up to 10 days after spraying had 32% inhibition, and birds collected 2 to 5 days after spraying had up to 50% inhibition of cholinesterase.

Connelly: I think the important point is the common thread - sage grouse in Idaho, pheasants in California, Monitor on potato fields, I think there is some hard evidence that's worth looking at by the scientific community.

Session 4. Frameworks for Longterm Monitoring

River Basin Studies: National Water Quality Assessment Program

Stuart McKenzie
U.S. Geological Survey

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EMAP: Relationship to Pesticide Studies

Daniel McKenzie
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River Basin Studies: National Water Quality Assessment Program

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The NAWQA (National Water-Quality Assessment Program) is designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources. To meet NAWQA goals, the program will integrate information about water quality at different spatial scales-- local, study unit, and regional and national.

As part of the program, study-unit investigations will be conducted in 60 areas throughout the nation to provide a framework for national and regional water-quality assessments. By 1993, 20 study units will be in an intensive data-collection and analysis phase each year, and the first cycle of intensive investigations covering the 60 study units will be completed in 2002.

National and regional assessments of ground- and surface-water quality will be provided from issue-oriented findings of nationally consistent information from the study units. By including study units that cover both a large part of the United States and diverse hydrologic systems that differ in their response to natural and human factors, the NAWQA Program ensures that many critical water-resource and water-quality concerns or issues can be addressed by comparative studies that are national and regional in scale.

Questions for Stuart McKenzie

Q. Do you have stable funding during this time period?

A. As much as any Federal agency has stable funding during this period of time. OPM had a meeting with us, and they said that unless we could turn out products - - and they wanted us to be able to move vertically and horizontally! They meant horizontally we had to interact with all other activities in the environment, that is with all other federal and local agencies, involved in this kind of work, and vertically, we had to be able to be aware of the whole range of contaminants in the environment.

Another thing, too - there has been some question about the difference between ourselves and EMAP. They are different approaches, and my sense is, we will be further ahead with the complement of the two, and so I'm in favor of EMAP.

Q. To what extent will data produced by this program feed into the other, I mean, is there a cost saving on both sides?

A. I'll let Dan answer that from the EMAP side. I think, definitely. I see EMAP as a national data set. It will produce maps which, for the general public will be very user friendly. For scientists it will help us understand something about geographic variability that we won't be able to pick up. We will be in 45% of the continental U.S., so we are going to miss some of it. I see a lot of real benefit to us. I think we will be able to give them a lot of ideas about how do things, how to sample.

EMAP: Relationship to Pesticide Studies

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ABSTRACT

The Environmental Monitoring and Assessment Program (EMAP) is a new program being developed by EPA's Office of Research and Development to monitor indicators of change in the condition of our nation's ecological resources. Specifically, EMAP is intended to 1) provide quantitative estimates of the status, extent, changes and trends in ecological resources on a regional basis over periods of years to decades, 2) monitor indicators of pollutant exposure and habitat condition and seek to identify possible causes of adverse conditions, and 3) provide annual statistical summaries and periodic interpretive reports on status and trends. Seven ecological resource groups form the basic structure of EMAP: agroecosystems, arid lands, forests, Great Lakes, near costal systems, inland surface waters and wetlands. This presentation will provide a brief description of the program and then discuss some of the future EMAP activities and information anticipated for Region 10. An example illustration will be discussed to show how the EMAP framework could be applied to State or local-level monitoring programs. Monitoring objectives and linkages to relative risk-reduction frameworks will also be briefly addressed.

Questions for Dan McKenzie:

Q. At least in the Western part of the United States, a lot of the land is controlled by the Federal government. How are you (unintelligible)

A. We don't have enough funds to have a hope of doing this alone at the level it needs to be done. We are trying to involve other federal agencies as much as possible. Probably we are farthest ahead with NOAA. We have a memorandum of understanding with them to combine the National Status and Trends program that they have underway with EMAP. With Forest Service, we are not quite as far along, but looking at the Forest Health Monitoring Program that the Forest Service is putting together, and again, we are planning to run that as a joint office running one program, them with their objectives, EMAP with theirs, but integrated, one program. We've had some initial talks with BLM, Fish and Wildlife, etc., on a case by case basis but with each agency, it's an effort to get to a coordinated program.

Q. [Question on fishing lakes.] Here in the northwest, some of the lakes are managed as "put and take" fisheries. So the question of health may only be whether or not it will sustain a 9 inch trout long enough for someone to catch it!

A. Well, one of the things we need to look at is, how to take a measurement on a lake, take an indicator of it's condition, and judge whether that's good or bad, nominal or sub-nominal. The designated use concept comes into plan. Most of those 3 things are probably in conflict. If you have good fishing you probably don't have really clear water, and you probably don't have good biotic integrity. You probably managed it for a "put and take", so you probably need to say, "For use, how is it doing?" For each region what we are going to want to know is, is it as good as it was last year?

Q. In the early discussions that I heard about EMAP, it was supposed to be run on kind of a {?} volume basis, where you look at wetlands, you look at estuaries, you look at timberlands. Is that still part od the program?

A. Yes, what you see in this population for region is those particular categories. The population of lakes, population of wetlands, population of riparian habitats. In each of those resources we've tended to have between 6 and 20 categories of resources that we wanted to talk about.

[end of tape]

Q. You have a slightly different suite of indicators for each of your ecosystem types. One thing that I have been puzzled about is, if you are measuring, for a particular site or ecosystem, changes in the ecosystem, for example, cut down the forest and plant wheat there, which has a different suite of indicators, how would you get continuity there?

A. One answer is, EMAP is not claiming to know much about one particular site, In terms of classes that are changing, forest to ag, wetlands to ag, or ag back to forest, we will get that through land use characterization efforts every 5 or at most, 10 years. we will pick up how much change has occurred from one classification to another. The other will be, for example for wetlands, we plan to have to add maybe 5% per year just to keep a reasonable sample size because some are going to destroyed, we need the ability to pick up created wetlands or some activities that add wetlands.

Q. I used to study vegetation by the point plot method, pushing a steel point down until it touched a leaf, and I imagine a giant steel point coming down out of the sky and establishing this data point out of 21,600. Is that how it's done? and what happens after on the ground after that? Which personnel goes out and looks at that point?

A. Well, yes, it was kind of a random point from the sky. Actually it was this grid was laid out randomly. Once the grid is laid out and you have this 40 sq km hexagon, and that's sort of our initial guess at how big a piece of real estate you need to look at to look for the kinds of patterns we are looking for, and if you do that you have looked at 1/16th of the total area of the country. We are also looking at some things with less resolution but look at everything, like the AVHRRs, or the larger pixel size satellites to get walk to wall coverage. but once you get the sample and there is a lake in it, then a field crew is going to go out and collect fish, water, sediment, on the site, and those would be analyzed.

Q. OK, that's the lake, but are you then going to do one thing for waterways and then another to characterize the dry land ecosystem, saying is this forest, is this . . .

A. No it's the same approach for both, remember the layers? At each point, from the GIS system there will be a layer for lakes, a layer for streams, a layer for forests a layer for wetlands, a layer for agricultural types. So we will have all those types, full landscape characterization.

Q. I have a feeling you are mixing - - kind of, the GIS thing is really broad scale indicators. And then when you send a crew in you are really looking at small scale things, and in those small scale things there is a lot of variability, and over 10 years, that's a long wait! How will you match that to the broad scale maps, and how will you account for the variability that you are going to get in your satellite data. It seems to me you are trying to relate unrelated things in a very basic sense.

A. Clearly we have a scale problem, but one other thing, in terms of indicators: we need to get real good at selecting indicators. We want indicators that are very integrative, that tell us about what happened in the last year, not in the last five minutes. So maybe it's bio-accumulation in fish, or presence or absence of fish, not something that has a lot of noise. The other thing is to measure a lot of sites within the region. My experience is that the between site variability is greater than the within site variability. Which means that to talk about a region, I need more sites. I need more information on more sites, and less information on each site. To say that's all I need is not the answer. You need the reference site information, you need the process kinds of information from the more detailed studies to help you interpret that. To take water chemistry studies from one stream would probably not make much sense if you only went out there once a year.

Q. Will you be able through your sampling to detect changes like the rate of decline in sage grouse and decline in pheasant populations, would these parameters be able to pick up that?

A. One answer is, I don't think EMAP will ever come up with a population [count] of pheasants or fish for a site. I don't think we will ever quantify the population. In the indicators we have looked at so far, it looks as though we can detect changes of 2% to 3% per year over a decade.

Concluding Panel Discussion:

Strategy for a Better Understanding of Ecological Effects of Pesticide Use

Panelists: Wayne Landis, Western Washington University
Stewart McKenzie, USGS
Rick Parkin, EPA Region 10
Tom Pfleeger, EPA-ERL

Wayne Landis

The thing that struck me was the commonality among people who like birds, and the people who like things that get wet, in the kinds of questions we are asking. There are times when I thank God that water exists, and you can study organisms in it. It is an excellent buffer, and I feel sorry for the terrestrial people. Sometimes I think they should just study amphibious organisms, that stay in the water part of the time. But questions that they are asking are basically same:

What should we look at? If we find something, do we really care about it? and can we make some kinds of management decisions, what kinds of scientific conclusions can we reach on the basis of what we see?

If you have dead grouse, is that any more important than having no cladocera in a stream? the same kinds of questions.

The other thing is, how extraordinarily naive we are. WE don't really know very much, I wish we could put things together a little bit better. That gnaws on me as a scientist, and also it worries me when a local citizen's group calls up and says, "They just treated the pilings here with an arsenic compound, is that going to affect Bellingham Bay?" and they want to know that for free. Or someone says, "My neighbor is using a particular pesticide. Is this going to affect my drinking water, is this going to affect the fishery?" And even if we figure something out,it's probably only good for that case. I'd like to see a lot more integration across discipline lines, and a lot more discussion, because I think there is a lot more commonality than we'd like to admit.

I have stood up here and tried to say interesting things about biomarkers. I think that we should not be so concerned about labels, but should try to determine whether this information I am getting is good, and will be useful. That should be the criterion, not whether we get paid for it. And, can it be applied to the next level - is going to be useful in studying a population, or to a vertebrate biologist.

Stewart McKenzie

I have four quick things to say:

When you start out in a data collection program, Please start with an objective or question. Define it as specifically as you can. Then decide how you are going to interpret data that will satisfy your question or objective. If you know you have a system of analyzing your data that will help you meet your objective, that's going to help you an awful lot. The tool you are going to use defines the amount and kind of data that you are going to need to adequately answer your question.

Research is the thing that's going to make differences in the world. When we work in the field, we do our initial extractions right in the field, then we are ready to go to the laboratory. We know we are going to analyze for 44 compounds. We can analyze for nanograms per liter now. We filter a sample of from 5 liters up to 200 liters, and we extract the sample from what's left on the filter. The detection level is variable, because of the volume of sample we use, and because of the ability of the analyst to get rid of noise, to see a difference between signal and noise.

The final thing to look at is the significant figures. One. When I talk to analysts that are doing this kind of work, this is about the level of confidence you can have, one significant figure.

Finally, you are likely to encounter something completely new along the way. We had been extracting with solvent from wet samples. The Oregon Graduate Center thought they had a method used in air quality sampling, that would enable us to sample from suspended matter in the water. They got rid of the water, then extracted with solvent. They got five times the levels of some contaminants, that we had been getting. What we think is that when a particle of suspended material is surrounded by water, it is much more difficult for an organic solvent to get in and extract the contaminant.

We are concerned that our methodology may change as we go along, because when we look at our results we will have to say, "Yeah, different, but - look what happened to our methods along the way."

Rick Parkin

When I first came into the pesticide program, one and a half years ago, we were right in the midst of a comparative risk project. Headquarters had finished theirs, and Region 10 was doing their version of it, Both versions came to the conclusion that pesticides rank high in terms of human health risk and environmental risk, much higher than things like Superfund, and so forth, but neither study had a lot of data to back that up. It was professional judgement, some call it 'opinion'.

So they asked us, as we were in the high risk program, to do some daydreaming and come up with some projects to lower that risk. The first thing we said was, "Well, we don't know how much risk there is, [so] we won't know if we lower it", and the second was, "We can't believe there's no data out there. You mean we allow the discharge of all those millions of pounds of active ingredients and we don't require them to monitor it in any way. In an NPDS permit we allow a few hundred pounds of turbidity units, and we require them to at least monitor to see if they are putting in what they said they would, if not to monitor the effects in the water body itself." And the answer was, no, we don't do any monitoring of all that. We asked if we should be doing it, and second can it be done, and if it can be done, show us how, and help us do it.

And FIFRA, I believe Section 20 of FIFRA, actually gives EPA the authority to do monitoring, doesn't give them any money to do it, but says the administrator of EPA can do the monitoring he feels is necessary to insure that there are no unreasonable or unexpected risks occurring.

What we are asking this group to do, and what we will be asking people who participate in the future, is answer those questions for us. I think we have answered the question, should we be doing some monitoring, I think the answer is "yes", and I think some people think we can do something meaningful. The key words I heard earlier in the conference were "coordination". We may not have to do a lot more than we are doing right now, we may just have to coordinate ourselves.

We are taking some low budget steps right now to do that. I think we might be able to get more money. If nothing else we are a pain in the ass to headquarters trying to get money and talk them into doing things our way, and we usually get at least a little bit of our own way, and so I'm optimistic that we might be able to move this process forward, if nothing else we can throw a lot of energy at it. I think this conference that Mike put together and threw a lot of energy at is a great first step. And so I guess that I would ask that those who attended and especially those who are still here, the hardy ones, is that you will help us, when we try to collect information on what you are working on, and when we ask you for help in answering some of these questions, and when Mike calls, take a few minutes to him for a few minutes, it's an interesting experience, if nothing else!

Tom Pfleeger

I think it's fitting that I'm last. When I was asked to be on this panel I didn't realize that I was going to have to make a statement.

It occurred to me when I was sitting up there, It occurred to me that we didn't have anyone else talking about terrestrial plants, and that's my field of expertise, so I guess I am supposed to talk about terrestrial plants. And I think from my perspective they are a connecting mechanism for all these other organisms, because they are a source of carbon and energy for ecosystems, be they aquatic or terrestrial, and terrestrial plants are exposed to the atmosphere continuously, and are a good monitoring mechanism.

We heard how in aquatic systems, plants lack the lipid systems that make other organisms good monitors, but in terrestrial systems, we know that conifers have the ability to take up lipophilic compounds, and you can watch that, because the needles stay on the conifers for a number of years, so there's a mechanism for using plants. Also, in this concern about low levels of toxicants, specifically the new herbicides where we don't have the analytical techniques to measure them, we can use plants to biomonitor. Specifically, it's been suggested that very sensitive species such as sugar beets be set out in a field in pots and can be used as an indicator of a toxicant when analytical methods are not appropriate or are impossible.

Another way plants can been used in a test is a method that will be published next year: we have known for a number of years that when a pesticide is applied as much as 50% may be lost from the targeted land as drift, and another large proportion of the chemical volatilizes, but it is currently unknown where that goes, whether it goes to ecosystems or is lost to the atmosphere. And recently it has been shown conclusively by a group in California that material that volatilizes does move into adjacent ecosystems. They placed potted plants in adjacent fields after application of the pesticide, and they were affected. So I think plants do have a role, and we shouldn't overlook them.

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